FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by H. M. STEVEN

VOLUME XI

Published by the
OXFORD UNIVERSITY PRESS
LONDON: HUMPHREY MILFORD
AMEN HOUSE, E.C.4
1937

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THE MORE RECENTLY INTRODUCED CONIFERS AND THEIR VALUE FOR PLANTING IN THE BRITISH ISLES

BY W. DALLIMORE, I.S.O., V.M.H.

FROM the time when the Jesuit missionaries, David, Delavay, and Farges, began sending to France dried specimens of plants collected in western and central China, and the late Dr. (Professor) Augustine Henry, when in the employment of the Chinese Imperial Maritime Customs and stationed in Ichang between the years 1882 and 1900, collected and preserved specimens of the flora of that region for the Herbarium in the Royal Botanic Gardens, Kew, botanists knew that the Chinese flora included a very large number of species of trees, shrubs, and herbaceous plants that were unknown in Western gardens, but were likely to be of considerable use for outdoor cultivation in the British Isles if living plants could be introduced. Now and then seeds of interesting trees were received, as when Père Farges sent a parcel of seeds of *Davidia involucrata* to M. Maurice de Vilmorin at Les Barres in 1897. This tree was discovered by Père David in 1869 and its curious flower heads, each of which is attended by two large white bracts, had excited interest for nearly 30 years before a living plant was seen in Europe, but of the seeds received only one germinated. There was also the case of *Pinus Armandi*, seeds of which were received at Kew from Dr. Henry in 1897 as *Pinus sp.*, and it was not until it coned in 1909 that it was known that good trees of this rare and interesting species were in cultivation. Even then it was found that trees 2 years older were growing in France. However, the collectors referred to had neither the time nor the convenience to collect and send home large consignments of seeds and living plants, and few of the many available species were introduced before 1900.

Dr. Henry and the late Sir W. T. Thiselton-Dyer were largely responsible for inducing the late Mr. James Veitch, of Messrs. Veitch of Chelsea, to send out a collector to western and central China. The man chosen was Mr. E. H. Wilson, a young student gardener from Kew who not only possessed the necessary energy and enthusiasm but was also a good botanist. He started on his first journey in 1889 and was fortunate in being able to visit Dr. Henry in Ichang and obtain from him much valuable information on the plants of that region. A number of plant collectors had visited China many years before Wilson, notably Fortune, Oldham, and Maries, and they had introduced a number of very useful garden plants. They, however, had not penetrated to central and western China, hence Wilson found himself on practically virgin ground, and he made full use of his opportunities, as did his successors, Farrer, Purdom, Forrest, Kingdon-Ward, and others. Amongst the many hundreds of new plants introduced were numerous conifers, and it is to these and others recently received from other places that I wish to direct attention in this article.

Two definite interests must be taken into account in any consideration concerning newly introduced trees, firstly their use to the arboriculturist for decorative planting, and secondly their prospective value for planting under silvicultural conditions for commercial purposes. It is here that the arboriculturist works hand in hand with the forester, for he, with his greater conveniences and untrammelled by profit and loss accounts, can conduct experiments and try out trees under varying conditions, at a cost that would be prohibitive to the forester. The arboriculturist must try new trees for many years under a great variety of conditions before he can advise foresters to undertake their cultivation in trial plots. He must also ascertain the viability percentage of imported seeds, the conditions under which the best seed germination is obtained, the rapidity of the growth of seedlings, the percentage of first-grade plants to that of second grade and culls, the soil conditions under which the best growth is made, the liability or otherwise of seedlings and young plants to injury by winter cold, and frosts and cold winds in spring, the liability for young trees to be attacked by insect pests and fungus diseases, or their comparative immunity from such attacks, and he must find out whether regular and large consignments of seeds are available. He must also compare the rate of growth with that of well-known allied trees, find out whether a reasonably rapid rate of growth is maintained or whether, after a few years of vigorous growth, the vigour of the tree suddenly declines, and it appears unlikely that it will grow to a profitable size. A species must also be compared with allied trees, in order to find out whether it possesses any superior qualifications or advantages over those already grown under forest conditions, such as more rapid growth, ability to grow under conditions that are inimical to the well-being of better-known species, such as being specially adapted for planting on poor soils, in exposed places, or in positions subject to severe frosts in spring. A new species should also produce better, or at any rate as good, timber as a better-known species with which it must compete, and it should be less subject to attacks by insect pests and fungus diseases. With all this to consider, it can hardly be a matter of surprise that so few trees pass the test of the arboriculturist and are passed on to the forester.

Many of the newer Chinese conifers, with a few introduced from other countries, have now been in cultivation in the British Isles between 25 and 35 years, and from what can be judged there is not one that is likely to be of first importance to the forester. The Serbian spruce (*Picea Omorika*), originally discovered in 1875, and introduced to Kew in 1889, is the most promising of the newer trees. It appears to be particularly well adapted for planting on wet land in places subject to late frosts. In such a position in the Bedgebury Pinetum it grows vigorously and has not once been injured by spring frosts that have seriously crippled the European spruce, Sitka spruce, the newer Chinese species, and others. Unfortunately the natural distribution of the Serbian spruce is restricted to comparatively small areas on the banks of the river Drina, and there is difficulty in procuring large quantities of seed. Young trees in a forest plot at Bedgebury are growing very well.

The only other new conifer that at present suggests possibilities for the forester is *Cupresso-cyparis* (*Cupressus*) *Leylandii*. This is a hybrid between *Cupressus macrocarpa* and *Chamaecyparis nootkatensis*. It appears to be particularly hardy and to grow freely both in rather wet and in well-drained ground. Moreover, in low wet places it has not been affected by spring frosts. Although the timber has not been tested, it should be of good quality, considering that both parents produce good timber. Although it is not propagated by seed, cuttings root well in cold frames, and plants so raised produce good leading shoots. It is a tree that should be given a trial in a forest plot.

In the following notes some of the newer species of Conifers are passed under review with comments as to their peculiarities in the south of England. The south of England, however, is not the best region to test these trees, for in some parts comparatively mild winters prevent trees from high elevations getting a sufficiently long rest, growth is hastened by mild weather during winter and early spring, and young shoots are often crippled or killed by frosts and cold winds in May. In places where there is greater and more prolonged cold weather in winter, growth is retarded and there is less danger of injury in spring.

Amongst the larches, *Larix Potaninii*, and several forms of *L. Gmelinii* (*dahurica*), are the principal new introductions. *L. Potaninii* is closely related to the Himalayan *L. Griffithii* and appears to be as difficult to grow. Six trees were planted at Bedgebury in 1925. They were then about 2 feet high and very similar in size and age to young trees of European and Japanese larches planted at the same time. Only two of *L. Potaninii* as originally planted remain, and the tallest is barely 6 feet high, whereas European and Japanese species are all alive and some are 35 feet in height. Trees planted at later dates, as *L. Potaninii*, appear to differ in growth from the original trees, and to come into leaf earlier, but it is yet too early to determine whether they are correctly named. *L. Gmelinii* var. *Principis Rupprechtii* grows rapidly in some places and develops very long and broad leaves. However, it breaks into leaf very early in the year and is very liable to injury by spring frosts. This tree grew much faster at Kew than it has done at Bedgebury.

Of the spruces, *Picea asperata* and *P. likiangensis*, both Chinese species, grow well and form handsome decorative trees, but they are liable to injury by spring frosts. When grown as decorative trees they are inclined to develop with a dense branch system, and the lower branches grow so fast that they are likely to interfere with height growth if they are allowed to develop unchecked. *P. likiangensis* var. *purpurea* (sometimes referred to as *P. purpurea*) has shorter leaves and a less heavy branch system than the type. *P. brachytyla* is one of the handsomest of the newer Chinese spruces. It belongs to the flat-leaved section of the genus, and is thus closely related to *P. sitchensis* and *P. Omorika*. It is of graceful habit and the leaves are heavily silvered on the under surface. As a garden tree it has much to commend it, but it is liable to injury from frost in May. *P. Wilsoni* is another Chinese species. It forms a small tree 40 feet high in a natural state. Here it is seen as a slow-growing tree with slender

branches and long, slender green leaves. It is very susceptible to frost injury in May and appears to be difficult to grow.

The Japanese *P. Koyamai* grows as a lightly branched slender tree. When young it grows fairly rapidly, but we find at Bedgebury that the rate of growth slows down after about 10 years. Although it grows until late autumn it has suffered less from frost injury at Bedgebury than the Chinese species. *P. morrisonicola* is a rather tender tree introduced from Mount Morrison in Formosa. There are several healthy trees at Bedgebury, although growth is slow even in a carefully selected and sheltered place. One of the most beautiful spruces of comparatively recent introduction is *P. Breweriana*, from the Siskiyou Mountains in north-west California and south-west Oregon. The secondary branches are pendant, and they droop for many feet. The leaves are dark green. It was introduced to Kew in 1897, and the original plant is growing near the Pagoda. The most perfect specimen I have seen is growing in Mr. Cannon's garden at Vernon Holme, near Canterbury.

Several of the Chinese firs form very decorative trees where they thrive, but they begin to grow early and are very liable to injury by frost and cold winds in May. The Chinese firs form the most unsatisfactory group of trees at Bedgebury. They grow well for a year or two and are then crippled by frost. In the severe frost that occurred on the night of 16–17 May 1935, several species were cut back into 2-year-old wood. Young trees crippled in two successive years became very stunted and were then attacked by a species of *Dreyfusia*. *Abies Forrestii* is one of the best known of the newer Chinese firs. It is very distinct by reason of its reddish branches, dark green leaves with a silvery under-surface, and purple cones. There are two or three closely allied species which are rare in cultivation. Of these the most recent is *A. Georgei*, and it is likely to become the best known. Other of the newer Chinese firs are *A. recurvata*, in which some of the leaves turn backwards, *A. squamata*, peculiar by reason of its loose shaggy bark, *A. Kawakamii*, a native of Formosa, and *A. koreana*, a Corean species which is less liable to frost injury than those previously mentioned. The last named grows slowly, forming a small, dense tree covered with rather soft, dark-green leaves with a silvery reverse. Cones are borne freely by very small plants. They are violet-purple, with whitish seed wings extending a little beyond the scales.

The pines introduced from China under the names of *Pinus tabulaeformis* and *P. sinensis* are synonymous, the former being the correct title. The tree has decorative value but gives no promise of being a success under forest conditions. It is very susceptible to attacks by pine-shoot tortrix moths, but does not appear to be frost-tender. *P. funebris* is a very similar tree, and is probably a form of *P. tabulaeformis*. *P. Armandii* is a five-leaved pine rather similar in appearance to the Bhutan pine (*P. nepalensis*), or *P. excelsa*, as it is more often called. Its foliage is less dense than that of the Himalayan species, and many of the leaves do not exist for a second year. The cones are shorter and thicker than those of *P. nepalensis*. Although a useful garden tree it has nothing to recommend it for commercial planting.

Tsuga chinensis, *T. yunnanensis*, and *T. formosana* are three of the newer hemlocks. None has any advantages over better-known species, and all three are more tender to spring frosts than the American hemlocks.

Thuja koraiensis is a new arbor-vitae from Corea; it is inclined to develop with several leaders from a common base, and forms an interesting tree, though it appears to be susceptible to injury by honey fungus.

Taiwania cryptomerioides is a Formosan tree that grows to a large size in its native country, nearly 200 feet high, and up to 20 feet in girth of trunk. However, it is not very hardy and should only be planted in the mildest parts of the country. A plant at Bedgebury has stood out with some protection in winter since 1925, but it grows very slowly and has no leader. *Taiwania* is closely related to *Cunninghamia* and most closely resembles *Cryptomeria japonica* in appearance. There are several new kinds of juniper, of which the best known is *Juniperus Coxii*. It was sent to this country as the 'coffin juniper', and appears to be closely related to *J. recurva*, though it is of more rapid growth, and it may be a well-marked variety of that species. It grows into a handsome, decorative tree.

Although these do not exhaust the more recently introduced conifers, they include many of those that are in general cultivation.

NOTE ON NATURAL OAK FORESTS OF SOUTH-WESTERN IRELAND

BY BARRINGTON MOORE

VALUE OF A NATURAL FOREST.

IN lands subject to human activities for such a long time as the British Isles, it is unusual to find a forest which can, with any reasonable degree of assurance, be considered as natural, especially one that has been relatively little disturbed by cutting or other interference. Such a forest still exists in south-western Ireland.

To the forester, a natural forest is of the highest value as an indication of the productive capacities of the climate and soil, and as a guide to safe methods for making the most of those capacities. The lack of such a guide, or refusal to use it where it exists, is likely to lead to costly mistakes, discovered only many years later, as the Germans found after growing pure spruce where broadleaf trees grew before, and now recognize as the *Fichtenomania*. In the United States the Forest Service has for some years been reserving sample tracts of virgin forest representative of all the important forest types. In the eastern states, where only a few remnants of the virgin forests are left, the Forest Service has been willing to pay the very high prices resulting from the scarcity and quality of the timber in order to acquire some of these rare forests and preserve them for research in forest ecology necessary to the development of sound silviculture.

LOCATION.

The natural forests of oak referred to in this note are found in the extreme south-western corner of Ireland, just west of the small but very beautiful town of Glengarriff, and on the slopes above Lake Killarney, as well as on Ross Island in the Lake. There are not only small remnants, but solid bodies of forest up to several hundred acres or more in extent.

CLIMATE.

The climate of south-western Ireland is unusually mild for its latitude, milder than any other part of the British Isles. Tansley (6) calls attention to the remarkable north-westerly swing of the January isotherm 5° C. (41° F., Table I) which brings the winter temperature of the Mediterranean Riviera almost to south-west Ireland and permits the growth of such a distinctive Mediterranean plant as *Arbutus unedo*.

The records of precipitation and temperature for Killarney and Cahirciveen (Valentia Observatory), about 30 miles west of Lake Killarney, as well as the record of bright sunshine for Cahirciveen, are given in Table I. The precipitation record covers the years 1881 to 1915, and the temperature record the years 1901 to 1930, as the Meteorological Office has no computations of precipitation

for the period 1901 to 1930. However, the records are sufficiently long in this rather uniform climate to give reliable averages, and they present a picture of the climate of the region sufficiently accurate for the present purpose. As one of the interesting features of these Oak-holly forests is the occurrence of a podzol described later, it would have been useful to have had records of evaporation, but unfortunately there are none. However, it is more than likely that the rainfall here exceeds the evaporation.

TABLE I—*Precipitation (inches) and temperature (degrees Fahrenheit) at Killarney and Cahirciveen (Valentia Observatory), County Kerry, and bright sunshine at Cahirciveen.*

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
						Precipitation (inches)							
Killarney (1881–1915)	5·92	5·22	4·71	3·31	3·08	2·91	3·32	4·42	3·58	5·37	5·61	7·28	54·71
Cahirciveen (Valentia Obs.) (1881–1915)	5·49	5·20	4·54	3·67	3·17	3·20	3·78	4·79	4·14	5·57	5·76	6·64	55·65
						Temperature (degrees F.)							
Killarney (1901–30):													
Maximum	48·8	49·3	51·7	55·5	61·5	65·4	67·9	67·0	64·4	58·5	51·7	49·1	57·6
Minimum	38·6	38·0	38·3	40·4	45·5	49·8	53·1	53·2	50·4	46·0	40·1	39·0	44·4
Mean	43·7	43·7	45·0	47·9	53·5	57·6	60·5	60·1	57·4	52·3	45·9	44·1	51·0
Cahirciveen (Valentia Obs.) (1901–30):													
Maximum	48·4	48·2	49·4	52·2	57·6	61·3	63·6	63·2	60·9	56·3	51·0	49·1	55·1
Minimum	41·3	40·2	40·3	42·2	47·0	51·1	54·1	51·6	51·6	47·9	42·7	41·5	46·2
Mean	44·9	44·2	44·9	47·2	52·3	56·2	58·7	58·7	56·3	52·1	46·9	45·3	50·7
						Bright sunshine (hours and per cent.)							
Cahirciveen (Valentia Obs.) (1901–30):													
Total hours	42	65	115	159	189	176	158	150	124	92	64	38	1372
Daily mean, hours	1·36	2·28	3·71	5·28	6·11	5·87	5·09	4·84	4·14	2·97	2·12	1·23	3·75
Per cent. of possible	16	23	31	38	39	35	32	33	33	28	24	16	31

It will be seen from Table I that the climate is not only mild but equable, moist, and rather cloudy. The precipitation is heavier during the autumn and winter than during the spring and summer, the 5 months from October to February inclusive having 28·83 inches (average of the two stations) compared with 26·30 for 7 months, March to September. However, the growing-season precipitation is ample. The temperature is remarkably uniform, with mild winters, no month showing a mean minimum as low as the freezing-point, and cool summers, no month having a mean maximum of as much as 70° F. (21° C.). The sunshine is only a little less than south-western England, Bath,

for example, having a yearly total of 1,523 hours, an annual daily mean of 4·17 hours, and 34 per cent. of the possible sunshine.

TOPOGRAPHY, GEOLOGY, AND SOIL.

The region is hilly. While the elevations are not very high, hardly over 2,000 feet on some of the highest points, the slopes are so steep and rugged that the impression is one of mountainous country. The predominant geological formation is the Old Red Sandstone, here represented by strongly folded beds of grey shale. Glaciation has left much outcrop of rounded ledges and steep cliffs, and a thin stony soil.[1] Limestones are absent, except for a small area at Lake Killarney, and the soils are in general acid and deficient in lime.

RELATION TO PAST FORESTS.

The present oak forests near Glengarriff and Lake Killarney are of special interest in that they are probably surviving remnants of forests, perhaps similar in composition, which covered not only this region but in all likelihood a large part of Ireland as well. Just how or why these extensive forests vanished it is difficult to say. But it must be remembered that Ireland is the seat of a very ancient civilization dating from 1,500 B.C. or earlier. The forests of Ireland have been, therefore, under the pressure of man and his grazing animals for some 4,000 years or more.

THE FOREST.

The following notes apply to rather small, but, as far as could be judged, representative samples of the forest. One of the distinctive features of this forest is the uniformity of its composition, aside from breaks due to rock ledges and to wet hollows.

Site. The site of the most important sample is a slope of about 15 to 20 per cent. gradient, facing south. There is a good deal of outcropping grey shale with almost vertical strata. The ledges have been polished by glaciation. Yet oaks grow on some of them, finding a foot-hold in the crevices.

Composition. The composition of the upper story is nearly pure oak (*Quercus sessiliflora*), with about 5 per cent. of birch (*Betula verrucosa* and some *B. pubescens*). An understory of holly (*Ilex aquifolium*) is characteristic. An occasional rowan (*Pyrus aucuparia*) comes into the intermediate story. Along the stream-courses the principle tree is alder (*Alnus glutinosa*), which grows to large sizes for alder, some trees attaining 18 inches D.B.H. by 40 to 50 feet high, with clear lengths of 15 feet and more. An element which distinguishes this from oak forests elsewhere is *Arbutus unedo*, which grows in some of the openings around rock ledges, attaining heights of 12 to 15 feet and more, the spreading trunk being a foot in diameter just above the base. It seems to be holding its own, as several seedlings were found.

[1] It has been stated that general glaciation did not extend south of the Blackwater river, just north of the area here considered. If the glaciation was merely local, it was at least sufficient to leave a very definite impress on the land-forms and soil.

Form and Size. The form of the oaks is that of trees grown in high-forest, as contrasted with the short-boled spreading crowned oaks of the oak-ash-hazel woods in south-western England which look more like standards over coppice than high forest trees (2). Considering the rocky site and rather poor stony soil, the trees are fairly straight boled. They have a diameter of 6 to 24 inches at breast-height, averaging around 11 inches, and are 25 to 30 feet high, with 10 to 15 feet of clear bole. Some of the old oaks on the hill-sides above Lake Killarney attain diameters of 36 inches, and have rather spreading crowns.

Age Classes. The stand is predominantly mature, though it is not even-aged, the trees appearing to be between about 60 and 120 years old. Pole and sapling sizes are lacking.

Stocking. The stand is fully stocked, with a crown density for the oaks of about 0·7. Where there is a full understory of holly the total crown density is about 0·9.

Natural Regeneration. The natural regeneration of oak is in refreshing contrast with that of south-western England (2, 3). Oak seedlings of 1 or 2 years old are evenly distributed, and in sufficient numbers for restocking if they were to survive. Of course, they cannot be expected to develop in the shade of the older trees, and there is a gap between these young seedlings and the main canopy trees. The uniformity in the age of the seedlings points to reproduction occurring at intervals, probably after a chance combination of favourable factors such as perhaps a good seed year followed by a low point in the population of mice or other destructive agencies. Holly regeneration is abundant.

Ground Cover. The ground cover under a full canopy of oak and holly is of leaves, bare of vegetation except for an occasional fern (*Polypodium vulgare*), moss (*Thuidium tamariscinum*) on the rocks, a little scraggly ivy (*Hedera helix*), and a few scattered plants of *Euphorbia hibernica*. Where holly is absent, there is a carpet of low under-vegetation, the dominant plant in which is *Vaccinium Myrtillus*. In fact, if Cajander's system of forest types, based on under-vegetation, were applied here, this particular site would probably come under the Vaccinium Type. The *Polypodium* fern is common, and there is a considerable amount of thin ivy which here does not form a continuous ground cover as in parts of south-western England. It does get up into the oaks and make a thick growth in the crowns of some of the trees, however, though others are free from it. Among other plants characteristic of the forest floor are *Potentilla erecta*, *Melampyrum pratense*, very little grass, and a little blackberry (*Rubus fruticosus*), with an occasional bracken (*Pteris aquilina*). *Oxalis acetosella* occurs only locally. On the whole, the under-vegetation is not thick or tall enough to hamper the reproduction of oak, but on the contrary probably favours it.

HUMUS AND SOIL.

The humus and soil are here unusually interesting and complicated, and give rise to a number of questions, the solution of which would afford useful

knowledge as to the conditions influencing the development of this forest and others as well.

Under an oak forest in a mild humid climate, even on a non-calcareous soil, one would expect a type of decomposition and mixing of the humus with the mineral soil which would form a true mull type of humus layer (5). Instead, we find layers of surface humus varying from well-decomposed to a definite raw humus and generally distinct from the underlying mineral soil. In only one place, under very old oaks, was any mixture with the mineral soil found. Even here there was a thick surface layer which could not be considered a true mull. In other places, under full shade of oak and holly, a thin mat of partly decomposed leaves (F layer)[1] and a well-decomposed H layer of about 2 inches thick lies on, but is not mixed with, a brown, stony, clay loam. Under oak of about 0·6 crown density where holly is lacking, the surface humus is black and peaty, about 2 inches thick, matted with *Vaccinium* and other roots, and is sharply separated from an ashy, grey, stony, sandy soil, an unmistakable podzol. The reddish-brown zone of accumulation which normally occurs below a podzol is not visible here, though perhaps some accumulation might be shown by analysis. On Ross Island in Lake Killarney, under a stand of oak and holly similar to the one described above, there is a very marked raw humus overlying a leached layer about 2 inches thick. The raw humus consists of a layer of several seasons' leaf fall about 1-inch thick, in which the structure is still distinguishable, below which is a mat of dry, granular, or fibrous grey material bound together with roots, and filled with fungus mycelium. This lies directly on the podzol, with very little well-decomposed black humus layer (H layer). In this case also no zone of accumulation is visible. The podzol overlies a dry, coarse, gravelly sand.

Podzol soils are well known to foresters in northern countries, and are generally attributed to the accumulation of raw humus which used to be, and still is, rather widely considered the result of the slow rate of decomposition under low temperature, though Romell (4) has recently shown that it is not so much a question of *rate* as of *type* of decomposition. It is, therefore, not surprising to find the podzol under the raw humus. But why the raw humus? It has been suggested that the high rainfall keeps the soil so wet as to produce the same type of decomposition that occurs with low temperature. It is also difficult to explain why in places where the humus is well decomposed there should be the formation of a podzol, and a sharp demarcation between the humus and the mineral soil. Possibly the heavy precipitation is sufficient to cause leaching of the mineral soil, even though the water has not previously passed through a raw humus. The kind of surface vegetation may also have something to do with it, as the podzol occurs under the *Vaccinium* and is sometimes absent under a cover of dead leaves. But why the sharp line of separation between the humus and the mineral soil? Perhaps the explanation is to be found in the view expressed by Lundegårdh (1, p. 170) that a mull requires earthworms to

[1] Hesselman's F layer refers to the upper layer, partly decomposed, in which leaf structure is still discernible; his H layer is the humus in which structure can no longer be seen.

mix the mineral soil with the humus, and here the sharp separation may be due to the lack of earthworms or other organisms to bring about this mixing. A further possibility is that the podzol under the well-decomposed humus is an ancient one, formed under past climatic conditions, and remaining under the present climate. In this part of Ireland buried forests of Scots pine (*Pinus silvestris*) are found in many of the bogs. These pine forests probably grew in the sub-boreal climatic period and were overwhelmed and buried by the growth of sphagnum accompanying the increasing moisture of the Atlantic period around 1,000 B.C. It is not unlikely that some of the podzol is contemporaneous with the buried forests of Scots pine.

SUCCESSION ON ROCK.

Some of the ledges have not yet been covered with oak forest, and afford an opportunity to see the stages in the rock succession (xerarch series). On account of the crevices there is a good deal of telescoping, as the crevices become colonized by plants of later stages without passing through the earlier stages. The first plants on the bare rock are several species of crustose lichens, followed by *Cladonia*. Then comes a moss (*Thuidium tamariscinum*) and later the stone crop (*Saxifraga tridactylites*). The next stage is heather, both *Calluna vulgaris* and *Erica cinerea*, with *Potentilla erecta*, *Solidago vergoria*, *Vaccinium Myrtillus*, and a little grass. The heather is invaded by trees, and clumps of birch, rowan, oak, and holly become established, apparently all at about the same time. At about this stage ivy makes its appearance, and grows more vigorously than in the older and denser oak stands. Eventually the oak crowds out the birch, except for a few scattered trees, and establishes the oak-holly type, which is probably the climax for the region.

LACK OF DAMAGE FROM FIRE OR GRAZING.

An unusual feature of this forest is the absence of signs of past fires. In fact, it is the only forest I have seen outside of the tropics where at least some indication of fire, however old, could not be found. The reason is, of course, the extremely moist climate. Cattle have access to the forest, but have done no damage that could be seen. The lack of forage probably serves as a protection against them as well as against sheep.

SUMMARY.

Natural forests of oak (*Quercus sessiliflora*) with an under-story of holly (*Ilex aquifolium*) are still to be found in the hills of south-western Ireland near Glengarriff and Lake Killarney on thin, rocky non-calcareous soils from the grey shale of the Old Red Sandstone formation.

The forest is rather uniform and composed of almost pure oak, about 95 per cent., with about 5 per cent. of birch (*Betula verrucosa* and *B. pubescens*). *Arbutus unedo* grows in some of the openings around rock ledges.

The oak is of high-forest form, and, considering the site, fairly straight-boled. The stand is fully stocked, with a crown density of about 0·6 to 0·7 for

the oak, and 0·9 including the holly. It is mature to overmature, but not even aged. The younger age-classes, pole and sapling sizes, are lacking. Oak seedlings are ample for restocking.

The dominant plant in the low carpet of under-vegetation is *Vaccinium Myrtillus*.

The humus is unusual for an oak forest in a mild, humid climate in that it does not form a mull, but a distinct surface layer, in places being well decomposed, and in others a true raw humus. It is not mixed with the mineral soil, which in most places is podzolized, though the usual zone of accumulation under the podzol is not visible.

No signs of past fires could be found, and no damage by cattle or sheep.

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THE INFLUENCE OF CERTAIN ACCESSORY FACTORS ON FROST INJURY TO FOREST TREES[1]

BY W. R. DAY and T. R. PEACE

II. TEMPERATURE CONDITIONS BEFORE FREEZING

The Problem.

IN the natural course of events trees become more frost-hardy as the temperature falls in the autumn, the process known as hardening; and in the spring as the temperature rises they become increasingly susceptible again. It is often suggested that unseasonably warm weather in the late winter or early spring is responsible for making trees susceptible to frost damage by causing premature awakening from the winter rest, and that later in the spring a warm spell preceding a frosty one may render the damage by the frost greater than would otherwise have been the case. Young trees lifted from the ground during the winter may be stored in a warm place, and it would be interesting to know whether this is likely to affect their subsequent susceptibility to frost injury; hence the value of experiments involving exposure to different temperatures before freezing.

Previous Work.

A good deal of work has been done on this question, unfortunately concerned for the most part with crop plants. It is generally accepted that exposure to low temperatures hardens plants, and that exposure to high temperatures renders them less hardy. In general, temperatures below those required for plant growth induce hardening, e.g. Harvey (12) gives 41° F. as the highest temperature that will cause hardening in cabbage, and temperatures sufficiently high to promote active growth have the opposite effect. Harvey (11) has also shown the hardening effect in elm, finding that exposure to 32° F. for 5 days was sufficient to harden elm seedlings so that they could withstand exposure to 23° F.; 5 days at 50° F. had a very slight hardening effect, while the same period at 68° F. had none. He also found that alternations of low and high temperature, which commonly take place in nature, were as effective as continuous low temperature, provided the alternations were not too frequent. It is not stated at what time of year these experiments were carried out, but the elms had been grown in a greenhouse at 65° F., and were apparently in active growth at the time. In another paper (12) he states the alternating temperatures had the same hardening effect on cabbage. But Dexter (7), working on wheat, alfalfa, cabbage, and tomato, failed to find that alternations of temperature had any greater hardening effect than the average of the temperatures used. A point of importance is the length of exposure to low or high temperatures required for the effect on hardiness to develop. As

[1] Continued from vol. x (2), p. 132.

mentioned above, Harvey (11) found 5 days sufficient for elms, while for cabbage (10) he found that some hardening had taken place after 24 hours' continuous exposure to low temperatures, and that the process was fully completed after 5 days. Exposure to high temperatures induced loss of hardiness in about the same length of time. Winkler (29), who worked on trees and shrubs, states that hardening and loss of hardiness are both quick processes, and that the lower the temperature the more quickly does hardening take place. Peltier and Tysdal (21) found that 11 to 16 days' continuous exposure was required for full development of hardiness in alfalfa. Salmon (23), working with winter wheat, found that hardened plants exposed to greenhouse temperatures lost some of their hardiness in 12 to 24 hours, and nearly all of it in 120 hours. Pfeiffer (22) says that spruce become accustomed to warmth in the spring in a very short time, but to cold much more slowly, and explains in this way the one-sided damage which often occurs to trees. One side of the tree becomes more susceptible than the other owing to the greater heat received during a warm spell in the winter or early spring, and, owing to the slowness with which it becomes hardy again, it is liable to damage by any freezing temperatures that may occur.

Material and Methods.

The refrigerator and the general methods used in the authors' experiments have already been described (6), but before discussing the work on accessory factors a few words of general explanation are required. In the 1930–3 experiments and in some of those carried out in 1934 one or at most two minimum temperatures were used. A small number of trees was subjected to each treatment and all frozen at the same minimum temperature. The number used for each treatment was usually 4, but varied on occasion from 3 to 8. It is realized that the use of such small numbers of plants is open to criticism, and may account for the contradictory results in certain groups of experiments. On the other hand, the use of small units permitted a larger number of experiments, and the effect of any factor can be judged by the general trend of these rather than by the result of any one of them. Small trees 2 to 5 years old, planted in pots, were used in all the experiments. When not in use they were kept in cold frames, protected from frost, but open during the day and on warmer nights. During experimental freezing, except when damage to the roots was under investigation, the pots were protected by sawdust or by electrical heating. The species used in the experiments were European (Eur.) larch, Douglas fir (Green variety), Scots pine, Norway spruce, Sitka spruce, *Thuja plicata* and pedunculate oak. As a comparison between the different treatments an arbitrary percentage scale of damage is used, on the basis, undamaged 0, slightly damaged 25, moderately damaged 50, severely damaged 75, and dead 100. The figure quoted under the heading 'Damage Percentage' or DP in the various tables is the average value for all plants in each treatment.

In the remainder of the 1934 and all the 1935 experiments 4 or 5 minimum temperatures separated by 1 or 2 degrees were used on each occasion, thus

enabling the 'Critical Temperature' (CT.) to be recorded for each experiment, that is the highest temperature at which half the plants were damaged. In certain cases the range of minimum temperatures was insufficient to include the critical temperature for each treatment. If the critical temperature lay *below* the lowest temperature used, this is recorded by adding the letter 'b' to the temperature given; if it was *at* or *above* the highest temperature used, the letter 'a' is added. Thus in these later experiments both the critical temperature and the damage percentage can be used as a basis of comparison.

Experimental Results.

The experiments on the influence of temperature conditions before freezing are set out in Table I. In most cases the treatments at high temperatures were carried out in incubators, and those at low temperatures in a refrigerator; both were usually, but not always, lighted. In general, it will be seen that the damage increases with the temperature to which the plants are subjected before freezing. In some cases this increase was very striking, for instance in the experiment of 9 April 1934 exposure to 70° F. raised the critical temperature by as much as 5° F. as compared with outdoor temperatures. The variation in amount of damage following different treatments is shown in Plate I, fig. 1. The hardening effect of exposure to temperatures near the freezing-point, and the converse effect of exposure to high temperatures were equally marked throughout the whole period, January to May, during which the experiments were conducted. In the latter half of this season the warmer treatments were conspicuous by their effect on the breaking of buds, or on the growth of newly emerged shoots, but in the early part there was no visible effect on the plants, the changes resulting in increased or decreased frost resistance being entirely internal. Nevertheless, the effect on frost damage was very striking, as is shown by Plate I, fig. 2. In a few experiments alternating temperatures were tried. In most cases the results from these were intermediate between those produced by continuous exposure to the two temperatures used. On 21 May 1931, however, alternations had a hardening value slightly superior to that of continuous exposure to low temperature, and on 20 April 1932 they resulted in as great a degree of susceptibility as did exposure to continuous high temperature, except when very short periods at the high temperature were used. The number of experiments is insufficient to throw light on any differences in behaviour that may exist between the different species. In general, they do not bear out the work of Harvey (11) on the effect of alternations of temperature on the hardening of elm seedlings.

There seems no doubt that quite short warm or cold spells in the spring could have a marked effect on the subsequent frost susceptibility of trees, and cold aspects probably increase these effects. The experiments on alternating temperatures suggest that the high day temperatures experienced in sheltered valleys would be offset by the low temperatures at night, and that severe frost damage in such places is due merely to the extremely low temperatures experienced, and not to forcing of the trees by the high day temperatures. Also,

TABLE I. *Effect of temperature conditions before freezing.*

Year.	*Date.*	*Species.*	*Length of treatment before freezing.*	*Treatment before freezing.*	*DP.*	*CT.*	*Frozen at.*
1934	20 Jan.	Scots pine	4½ days	69° F. 32° F.	85 32	22° F. 18° F.	11° F., 13° F., 15° F., 16° F., 18° F., & 22° F.
1932	9–10 Feb.	European larch and Douglas fir	4 days	81° F. 68° F. Alternate days at 80° F. & 39° F. 30–40° F. 51–57° F. 39° F.	81 81 69 44 31 31	.. ..	9° F. 15° F.
1932	20 Feb.	European larch	4 days	68° F. Alternate days at 68° F. & 33° F. 33° F.	50 42 0	..	12° F.
1933	22 Feb.	Sitka spruce	5 days	68° F. 66° F. Alternate 8 hrs. at 57° F. & 33° F. 7 hrs. per day at 68° F., remainder at 33° F. 37° F. 33° F.	50 33 17 17 4 4	..	12° F.
1934	24 Feb.	Sitka spruce	5½ days	70° F. Outdoors 33° F.	22 6 0	15° F. 11° F. 11° F.	11° F., 13° F., 15° F., 16° F., 19° F., & 21° F.
1933	6 Apr.	Sitka spruce	4 days	66° F. Alternate 6 hrs. at 32° F. & 45° F. Outdoors 32° F.	59 37 25 3	..	18° F.
1934	9 Apr.	Norway spruce	5½ days	70° F. Outdoors 33° F.	46 6 6	20° F. 15° F. 15° F.	13° F., 15° F., 17° F., 20° F., & 21° F.
1932	20 Apr.	European larch	4½ days	68° F. Alternate days at 68° F. & 33° F. Outdoors 33° F. Alternate 3 hrs. at 68° F. with 12–18 hrs. at 33° F.	58 58 33 0 0	..	22° F.
1931	21 May	European larch	5 days	57·5° F. 71° F. Outdoors 32° F. Alternate days at 71° F. & 32° F.	31 12 12 6 0		24° F.
1934	25 May	Norway and Sitka spruce	5 days	70° F. Outdoors 33° F.	61 54 29	24° F. 24° F. 23° F.	21° F., 23° F. 24° F., 26° F., & 30° F.
1933	30 May	Norway spruce	7 days	68° F. Outdoors 32° F.	30 0 0	..	24° F.

CT. = Critical Temperature. DP. = Damage Percentage.

on the basis of these experiments the storage of lifted plants under warm conditions during the winter is likely to be dangerous, and should be avoided.

III. TIME FACTORS.

The Rapidity of Freezing and Thawing.

The Problem.

Under natural conditions, freezing is usually a fairly gradual process. The temperature tends to fall slowly during the night, and the minimum is often reached at about dawn. The rate of thawing is on the average rather more rapid, and can be very fast, if, as often happens after a late spring frost, the following day is fine and sunny. Analysis of temperature-records taken in Oxford, and in Bagley Wood near Oxford, from January to June of the years 1934–7, gives the figures set out in Table II. The time taken for the temperature to fall from 35° F. to 25° F., and that for the temperature to rise over the same interval were measured for each frost, and the results divided into classes as shown. It will be seen that thawing is really rapid in a far higher proportion of cases than freezing. Also in the case of thawing the bulk of the periods above 2 hours were shorter than 6 hours, whereas in the case of freezing a good many of them lay between 6 and 10 hours. In both freezing and thawing, periods as long as 17 hours were counted; and during prolonged frosty spells, which were not considered in the analysis, this figure would often be exceeded.

TABLE II. *Period taken for the temperature to fall or rise over the range* 25–35° F. *at Oxford.*

	1 hr. or less. per cent.	*1–2 hrs. per cent.*	*Over 2 hrs. per cent.*	*Number of frosts analysed.*
Fall of temperature	5	23	72	43
Rise of temperature	32	25	43	37

By sheltering plants from the sun on warm mornings it is possible materially to lessen the rate of thawing, and it is obvious that the aspect chosen for a plantation will also have a considerable influence. It has also been suggested that the damage to plants after frost may be lessened by spraying them with cold water before they have thawed. Since the rapidity of thawing can, to some extent, be influenced artificially in the forest nursery, and since it is so definitely affected by aspect and situation in the forest, it is of interest to investigate its effect on frost damage. Though the rate of freezing is probably less important in nature, it does vary, and might influence the amount of damage done by frost under certain circumstances.

Previous Work.

A good deal of research has been carried out on this question. Rapid thawing was generally found to increase damage, as shown by Hildreth (13) and Beach and Allen (2) for apple trees, by Garcia and Rigney (9) for fruit tree buds and flowers, by Lutz (16) for apple fruits, potatoes, and onions, by Peltier and Tysdal (20, 21) for alfalfa, by Borthwick (3) for conifers, and by Pfeiffer (22) for spruce. Sorauer (25) was of the opinion that only frost-susceptible plants were affected by

rate of thawing, while Novikov (19) working with cereals and shrubs and Åkerman (1) working with trees, shrubs, and cabbage both state that rapid thawing increases damage provided the final temperature reached is not too low, when the plant is severely damaged in any case. Iljin (15) is also of the opinion that rapid thawing increases damage. On the contrary, Weimer (27) using alfalfa, West and Edlefsen (28) using fruit trees, and Diehl and Wright (8) using apple fruits all failed to find that rate of thawing affected frost damage.

Less work has been done on the rate of freezing, but rapid freezing has generally been found to increase damage. Chandler (5) using fruit trees and vegetables, Hildreth (13) using apple trees, and Carrick (4) using apple fruits agree on this; while Pfeiffer (22) working on spruce found that rapid freezing increased damage in the winter, but had no effect in the spring. Winkler (29) found that slowly frozen trees and shrubs could withstand 10° C. more cold during the winter than those that were rapidly frozen. Iljin (15) makes a general statement that rapid freezing increases damage; but Stiles (26) argues that in rapid freezing, smaller ice-crystals are formed, and therefore less damage done, supporting his opinion with experiments on living and non-living colloidal systems. Judging by the work quoted above, this argument would seem not to be generally valid for plants.

Experimental Results.

The results of the authors' experiments on these factors are set out in Tables III, IV, and V. Considering first rapidity of freezing alone, we see from Table III that in 5 out of the 6 experiments rapid freezing increased the amount of

TABLE III. *Rapidity of freezing.*

Year.	*Date.*	*Species.*	*Minimum temperature.*	*Damage percentages for*		*Time from 35°–25° F.*
				Quick freezing.	*Slow freezing.*	*slow freezing.*
1932	14–19 Dec.	Scots pine	16° F. and 17° F.	53	11	17 hrs.
1933	22–3 Jan.	,,	11° F.	42	8	3 ,,
1933	7–8 Mar.	Sitka spruce	9° F.	37	12	3 ,,
1933	18–19 Apr.	Douglas fir	23° F.	56	69	4 ,,
1933	8–9 May	Scots pine	18° F.	75	50	16 ,,
1933	14–15 May	Thuja	24° F.	50	31	5 ,,

damage, while in the experiment of 18–19 April 1933 the reverse effect was obtained; but the difference between the two treatments in this case was not very striking. Quick freezing in all these experiments indicates that the plants were moved straight into the minimum temperature from a room temperature which varied between 50° F. and 60° F. Such a rapid transition as this would happen in nature only under the most exceptional circumstances. In slow freezing, the plants were placed in the refrigerator at some temperature above

the freezing-point, the fall of temperature proceeding at the normal rate of cooling of the refrigerator. For comparison with the figures for natural conditions at Oxford, given in Table II, the time taken for the temperature to fall from 35° F. to 25° F. is given for each experiment. For the normal rate of cooling by the refrigerator this varied from 2 to 3 hours, and the longer periods were procured by stopping the refrigerator at intervals, the regular fall being interrupted therefore by one or more periods during which the temperature remained constant for several hours.

Rather more attention was paid to the question of rate of thawing (Table IV). Comparing only quick and slow thawing, it will be seen that rapid thawing increased the damage in 12 experiments, had no effect in 2, and decreased the damage in 2. That the effect of rapid thawing was often very marked is clearly shown by Plate I, fig. 3. Quick thawing indicates that the plants were removed from the refrigerator straight into room temperature, which ranged from 50° F. to 60° F. This is probably to some extent comparable with the effect of the sun falling on frozen plants in the morning. Slow thawing was controlled by the rate of warming of the refrigerator after it had been shut off; in many cases this was accelerated by heating with lamps or leaving the door slightly ajar. For comparison with Table II, the time taken for the temperature to rise from 25° F. to 35° F. is given.

In the 4 experiments where it was tried, thawing by immersion in very cold water (usually at about 33° F.) increased the damage as compared with quick thawing. This has been recommended as a treatment for frozen plants in pots, but unless trees are exceptional in this matter, it would appear to be quite ineffective. Spraying with cold water as a means of thawing plants could be more easily carried out in practice, and has been generally recommended as a method of mitigating frost damage. The results obtained in these experiments were not encouraging, because in 2 experiments only did it appear to lessen damage, in 1 it made practically no difference, and in the remaining 4 it increased the damage as compared with quick thawing. A few experiments included treatments to test effects of thawing in wind, but in most of these the effect on damage seems to have been attributable to rate of thawing rather than to the wind.

The experiment of 16–17 January 1935 is of particular interest as showing the lack of differentiation between the different treatments at very low temperatures, already noted by Novikov (19) and Åkerman (1). This effect was noticed to a lesser extent in other experiments where several minimum temperatures were used, but was never so striking, presumably because the temperatures were not sufficiently low.

Finally, in Table V we have the results of the experiments in which both freezing and thawing were considered. Here we are concerned with four treatments, quick freezing followed by quick thawing (QFQT.), slow freezing followed by quick thawing (SFQT.), quick freezing followed by slow thawing (QFST.), and slow freezing followed by slow thawing (SFST.). As before, the time taken for the temperature to fall from 35° F. to 25° F., and to rise

TABLE IV. *Rapidity of thawing.*

Year.	Date.	Species.	Min. temp.	Damage percentage for: Quick thawing.	Slow thawing.	Thawed in water.	Sprayed water.	Time from 25°–35° F. slow thawing.	Other treatments. DP. in brackets.
1932	17 Nov.	Norway spruce	16° F.	40	20	..	47	23 hrs.	
1932	13–17 Dec.	Scots pine	16 & 19° F.	39	8	..	..	16 hrs.	In current of wind slowly thawed (21).
1935	16–17 Jan.	Scots pine	11° F.	88	..	88	88		
			14° F.	75	..	88	75		
			15° F.	78	..	88	72		
			17° F.	56	..	62	31		
				(CT. all treatments 17° F.)					
1932	10 Feb.	Douglas fir	14° F.	25	8	..	..	12 hrs.	
1932	22 Feb.	Eur. larch	12° F.	83	83	..	..	12 hrs.	
1932	15 Mar.	Douglas fir	18° F.	42	17	..	..	30 hrs.	In current of wind, quickly thawed (75). In humid atmosphere slowly thawed (0).
1933	18–19 Mar.	Scots pine	18° F.	75	0	..	..	17 hrs.	
1933	24–6 Mar.	Eur. larch	15° F.	70	50	..	..	27 hrs.	
1933	27 Mar.	Sitka spruce	14° F.	44	..	..	59		
1932	8 Apr.	Eur. larch	21° F.	6	19	..	..	18 hrs.	In current of wind, quickly thawed (38).
1935	8–9 Apr.	Norway spruce	11, 13, 15, 17, & 18° F.	44 CT. 17° F.	.. .. ..	65 CT. 18° F.	43 CT. 18° F.		
1933	13 Apr.	Eur. larch	21° F.	12	..	..	9		
1931	6–8 May	Eur. larch & Douglas fir	24° F.	56	31	..	..	2–3 hrs.	
1933	13–14 May	Sitka spruce	24° F.	50	56	56	..	22 hrs.	
1932	14 May	Douglas fir	25° F.	50	33	..	..	16 hrs.	
1933	20 May	Eur. larch	25° F.	0	..	..	3		
1931	22 May	Eur. larch & Douglas fir	25° F.	44	25	..	..	7 hrs.	
1932	26 May	Norway spruce	24° F.	61	50	..	..	20 hrs.	In current of wind, humid atmosphere, slowly thawed (0).
1932	3 June	Eur. larch	24° F.	56	19	..	..	17 hrs.	In current of wind, dry atmosphere, slowly thawed (0).
1933	10 June	Norway spruce	24° F.	19	19	..	..	6 hrs.	
1931	12 June	Pedunc. oak	22° F.	67	56	..	..	16 hrs.	
1935	8–11 July	Norway spruce	22, 23, 24, & 25° F.	42 CT. 23° F.	.. .. ..	47 CT. 24° F.	27 CT. 25° F.		

CT. = Critical Temperature. DP. = Damage Percentage.

over the same range, is given for slow freezing and slow thawing respectively. It will be seen that quick freezing combined with quick thawing was always the most damaging, and slow freezing with the slow thawing the least damaging treatment, with the exception of the experiment of 25–6 April 1933 on European larch, in which there was very little difference between the treatments. The position of the remaining two treatments is less well defined. In 5 experi-

ments slow freezing combined with quick thawing resulted in more damage than quick freezing with slow thawing, in 4 experiments this position was reversed, while in one there was no difference between the two treatments. It is impossible to say from this whether freezing or thawing has the greater influence on the final damage. The difference in critical temperature between the two extreme treatments can be as great as 9° F., but is often very much less. Differences equally great can be found between slow freezing combined with quick thawing, and slow freezing with slow thawing, the two conditions most commonly occurring in nature. On the other hand, though differences in damage percentage exist in all cases, these are sometimes very slight, and there is often no difference in the critical temperature between these two treatments. The difference that can occur between the treatments is shown in Plate I, fig. 4. The experiment illustrated here is one where only the rate of freezing seems to have had any material effect on the amount of injury. Again, the number of experiments with different species is insufficient to form a basis of comparison. But it is of interest to note in Table V that in all the experiments with Scots pine, rate of thawing was of more importance than rate of freezing.

TABLE V. *Rapidity of Freezing and Thawing.*

Year.	*Date.*	*Species.*	*Min. Temp.*	*QFQT.*		*SFQT.*		*QFST.*		*SFST.*		*Time between 25° F. and 35° F.*	
				DP.	*CT.*	*DP.*	*CT.*	*DP.*	*CT.*	*DP.*	*CT.*	*SF.*	*ST.*
1933	11–12 Jan.	Scots pine	11° F.	42	..	23	..	15	..	10	..	2 hrs.	18 hrs.
1934	20–30 Jan.	Scots pine	..	38	18° F.	9	18° F.	9	16° F.	3	13° F.	2½ ,,	12 ,,
1935	22–6 Mar.	Scots pine	..	51	19° F.	40	19° F.	10	10° F.	1	10° F. b	2 ,,	5 ,,
1934	7–11 May	Sitka spruce	..	71	24° F.	71	24° F.	46	24° F.	29	24° F.	3 ,,	8 ,,
1935	27–30 May	Scots pine	..	69	23° F.	65	23° F.	50	23° F.	35	22° F.	3 ,,	5 ,,
1933	23–5 Apr.	Sitka spruce	21° F.	66	..	40	..	40	..	27	..	12 ,,	32 ,,
1934	24–8 Feb.	Thuja	..	71	16° F.	42	13° F.	50	13° F.	25	13° F.	2 ,,	11 ,,
1935	24 Feb.–1 Mar.	Thuja	..	45	20° F. a	13	11° F.	34	16° F.	1	11° F. b	2 ,,	6 ,,
1934	18–23 Mar.	Eur. larch	..	44	13° F.	4	10° F.	33	13° F.	3	10° F. b	2 ,,	11 ,,
1933	25–6 Apr.	Eur. larch	23° F.	41	..	31	..	50	..	44	..	11 ,,	29 ,,

QF. = Quick Freezing. SF. = Slow Freezing. CT. = Critical Temperature.
QT. = Quick Thawing. ST. = Slow Thawing. DP. = Damage Percentage.

It seems quite clear from the experiments described above that the amount of frost damage to conifers is likely to be affected at any time during the winter or spring by the rate of freezing and thawing. Since variations in the rate of thawing in nature are much more marked than those in the rate of freezing, thawing is probably the more important factor. The efficacy of shelter against frost is probably due not only to its influence on the minimum temperature reached but also to its retarding influence on the rate of freezing and thawing. Considering the striking differences in injury which can be brought about by quick and slow thawing, experiments in forest nurseries

with hedges and other means of sheltering plants from the morning sun till they have thawed might be justified; but it must be remembered that if the air temperature is low, such shelter may merely have the effect of postponing thawing till the sun is higher in the sky, and correspondingly more powerful, and thus increase the rate of thawing rather than lessen it. If frost-susceptible plants have been left unsheltered during an unexpected frosty night, damage might well be mitigated by covering them with some form of heavy shelter in the very early morning. Aspect is obviously important in connexion with rate of thawing, and there is no doubt that a slope receiving the morning sun has increased possibilities of frost damage as compared with one which is shaded till later in the day, by which time thawing would usually have taken place more slowly. In considering the effect of configuration of site on frost damage, this should be kept in mind in addition to the more important effects of topography on the flow and collection of cold air during frosts, and on the state of development of the vegetation.

The Duration of Freezing.

The Problem.

Temperature records taken in Bagley Wood near Oxford during the months of January to June 1935 and January to March 1936 have been analysed to discover the duration of the damaging frosts taking place there. The thermometer was situated in a cold valley where frost damage is quite common. Using the results of experiments on the low temperatures required to injure trees (6), a temperature below which damage to trees was considered likely was selected for each month. These temperatures ranged from 17° F. in January to 27° F. in June. During the period under consideration, there were on this basis 12 damaging frosts, though a few others touched the critical temperature without falling below it. The period over which the damaging temperatures lasted, that is to say the period during which the temperature was at or below the selected temperature for damage, varied from 2 to 7 hours, or, if the cases in which the temperature reached but failed to fall below the critical point are included, from 0 to 7 hours. If a winter such as that of 1928–9 had been included in these records very much longer periods would certainly have been recorded; but it seems likely that, in this country, the duration of damaging temperatures is usually rather short. It becomes a matter of interest to know how long a period of exposure to low temperatures is required to cause injury, and to what extent damage increases if the duration of exposure is extended beyond this time.

Previous Work.

In the past, practically all the data on this question have been incidental to other experiments, and are, therefore, usually incomplete. Naturally, the lower the temperature, the less time will be required for damage, and hardier plants will certainly require lower temperatures and probably longer exposure to injure them. In the absence of complete data it is difficult to compare the

various results recorded. As far as we are aware, the shortest time recorded for frost damage to plant tissue is that given for potatoes by Wright and Diehl (30), who state that some damage was apparent after half a minute at low temperature, and that damage increased with the duration of exposure, but the particular temperature used in this experiment is not given. Mobius (18) found that 1 minute at 13° F., or 2 minutes at 23° F. damaged begonias, plants which are very frost susceptible. In the first instance, the plants were at 63° F. before being moved into the freezing temperature, and during the exposure of 1 minute a mercury thermometer beside them fell only to 43° F., so that the damage cannot have been due to freezing, but in some way not yet understood, must have been caused by the sudden lowering of the temperature. Weimer (27) found that exposed alfalfa roots were killed by 15 minutes' exposure to —4° F., Beach and Allen (2) damaged apple twigs by 20 minutes' exposure to —10° F., while Harvey (10) was able to damage cabbages by 30 minutes' exposure to —3° F. In none of these experiments is it certain that this was the minimum period required to cause damage. With regard to longer periods, Hildreth (13) using apple twigs found more damage after 12 than after 3 hours' exposure to —22° F. in the winter; Hill and Salmon (14) using winter wheat found more damage after 24 than after 6 hours' exposure to —10° F.; Novikov (19) for cereals and shrubs and Garcia and Rigney (9) for fruit buds state that the damage increases with the duration of the frost; but West and Edlefsen (28) working also on fruit buds state that the duration of frost makes no difference. The most interesting work from the forester's point of view is that carried out by Schmidt (24) on spruce. Some of his results are set out in Table VI. It will be seen that 15 minutes was the shortest time in which he was able to procure damage, and at any rate up to seven or eight hours' damage increased with time.

TABLE VI. *Results of some of Schmidt's Experiments with Spruce.*

	Min. temp.	*Time of exposure.*	*Effect on trees.*	*Time of exposure.*	*Effect on trees.*
May	19° F.	1½ hrs.	Slightly damaged	7 hrs.	Dead
„	23° F.	5 „	„	11 „	„
June	25° F.	7 „	No damage	18 „	„
Aug.	24° F.	10 min.	„	15 min.	Slightly damaged
Sept.	23° F.	10 „	„	8½ hrs.	Dead
„	25° F.	4½ hrs.	Slightly damaged	14 „	„

Experimental Results. Experiments have been done on the effect of length of exposure, on damage due to low temperatures, and the results are set out in Table VII. Trees were exposed to the same minimum temperature for varying lengths of time, and the damage percentage in each case is given in the table under the times used. The normal critical temperatures at the time of

TABLE VII. *Duration of exposure.*

Year.	Date.	Min. temp.	Usual CT.	Species.	Damage percentage for Minutes. 1	2	5	10	15	20	25	30	40	50	Hours. 1	2	4	6	12	24	31	36	48
1933	11 Apr.	19° F.	20° F.	Eur. larch	0	..	6	12	41	38	50	63	41	72	66	..	..	..	..	..	..	..	..
1933	13 June	14° F.	23° F.	Scots pine	..	0	25	38	63	87	..	..	..	..	..	..	..	..	..	..	..	..	..
1934	1 May	18° F.	22–25° F.	Eur. larch	..	..	23	52	71	67	..	..	71	..	67	..	..	..	..	..	..	..	..
1934	4 May	24° F.	22–25° F.	Eur. larch	..	..	0	0	6	11	..	..	17	..	22	..	..	..	..	..	..	..	..
1934	8 June	20° F.	24° F.	Sitka spruce	..	..	0	8	25	58	..	..	67	..	75	..	..	..	..	..	..	..	..
1934	26 May	19° F.	24° F.	Sitka spruce	..	..	0	0	58	58	..	..	75	..	75	..	..	..	..	..	..	..	..
1934	26 May	23° F.	24° F.	Sitka spruce	..	..	0	0	25	17	..	..	42	..	58	..	..	..	..	..	..	..	..
1930	25 Apr.	17° F.	19–23° F.	Eur. larch	..	..	..	25	..	50	..	100	..	..	..	75	..	..	..	..	..	..	..
1934	6 Feb.	11° F.	17–20° F.	Scots pine	..	..	..	..	..	54	..	..	58	..	54	58	71	58	..	..	..	..	..
1934	6 Feb.	14° F.	17–20° F.	Scots pine	..	..	..	..	..	58	..	..	37	..	67	50	63	42	..	..	..	..	..
1934	7 Feb.	17° F.	17–20° F.	Scots pine	..	..	..	..	..	29	..	..	25	..	33	17	46	25	..	..	..	..	..
1934	7 Feb.	20° F.	17–20° F.	Scots pine	..	..	..	..	..	12	..	..	4	..	8	0	0	21	..	..	..	..	..
1934	10 Mar.	13° F.	16–17° F.	Douglas fir & Thuja	..	..	..	..	..	46	..	..	42	..	37	46	54	50	..	..	..	..	..
1934	11 Mar.	15° F.	16–17° F.	Douglas fir & Thuja	..	..	..	..	..	21	..	..	21	..	42	12	50	33	..	..	..	..	..
1934	12 Mar.	17° F.	16–17° F.	Douglas fir & Thuja	..	..	..	..	..	8	..	..	0	..	0	0	8	8	..	..	..	..	..
1934	13 Mar.	19° F.	16–17° F.	Douglas fir & Thuja	..	..	..	..	..	4	..	..	12	..	0	4	0	8	..	..	..	..	..
1934	25 Mar.	16° F.	14–16° F.	Sitka spruce	..	..	..	..	..	..	..	..	..	..	..	..	25	25	17	42	..	33	25
1934	27 Mar.	18° F.	19–23° F.	Eur. larch	..	..	..	..	..	..	..	..	..	..	..	..	75	58	50	58	..	75	67
1933	16 Jan.	9° F.	9 °F.	Eur. larch	..	..	..	..	..	..	..	..	..	..	..	..	..	21	0	59	..	..	59
1933	9 Apr.	19° F.	19–23° F.	Eur. larch	..	..	..	..	..	..	..	..	..	..	..	..	..	..	63	72	75	..	87

year, as recorded in other experiments with the refrigerator (6), are given for each species for comparison with the minimum temperatures used in these experiments. Obviously, if the temperature used in the experiment is very much below the critical temperature, damage would be expected in a shorter time than if the two temperatures were nearly the same. It will be seen that on 3 out of 7 occasions some damage resulted from 5 minutes' freezing, but that periods of 1 and 2 minutes proved insufficient to cause any injury. The experiment of 1 May 1934 suggests that if the temperature is sufficiently low the maximum amount of damage may be caused in as short a time as 15 minutes, but that of 4 May of the same year shows that if a temperature approximating to the critical temperature is used, injury increases with time, at any rate up to 1 hour. These two experiments also clearly indicate that the amount of time required for damage is to some extent dependent on the degree of cold

to which the plants are exposed. In the second experiment no damage developed after 5 or 10 minutes' exposure and very little after 15 minutes. During the first hour of freezing there is a general tendency for damage to increase with time, but in some experiments this tendency is very vague after the first 15 or 20 minutes. Comparing periods ranging from 20 minutes to 6 hours, as in those experiments set out in the middle of the table, only a very slight and very irregular tendency is noticeable for damage to increase with time. The same may be said of the experiments at the bottom of the table, which are concerned with times ranging from 4 to 48 hours. One can say that damage is possible in 5 minutes or perhaps even less provided the temperature is low enough, and will usually take place after 15 or 20 minutes' exposure below the critical temperature. An approximation to the maximum damage for that temperature is obtained after 1 hour's exposure and often after as short a period as 15 or 20 minutes. After this degree of damage has been attained, the increase with time is very slow and in many cases inappreciable. This suggests that in nature the duration of frost is not likely to be a matter of outstanding importance, since the length of damaging frosts is so often over 2 hours. But it does indicate that if the temperature reaches but fails to fall below the critical temperature, little damage will be done, for under these circumstances an exposure of 20 minutes or more would be required for damage to develop, and the temperature is unlikely to remain at the minimum for this length of time.

The Repetition of Freezing and Thawing.

The Problem and Previous Work.

Periods often occur in this country when it freezes several nights in succession, but thaws during the intervening days. Indeed, weather of this nature is one of the characteristics of our climate. We have already seen that frost damage is concerned with freezing and thawing as well as with low temperature, and it would seem possible that these repeated freezings and thawings might be especially injurious to the plant. Very little previous work appears to have been done on this point. Sorauer (25) reports that Göppert found in his experiments with *Euphorbia lathyris* that repeated freezings and thawings with a minimum temperature of 258° F. eventually killed the plants, whereas they could withstand a single exposure at 10° F. to 14° F. for a considerable period. Winkler (29) using trees and shrubs found that repeated freezings above the critical temperature caused damage, for instance plants repeatedly frozen at 9° F. were damaged, although they could withstand a single freezing at −4° F. But Diehl and Wright (8) found that, although repeated freezings and thawings caused more damage in apple fruits than a single exposure to the same temperature, prolonged exposure to that temperature was even more damaging. Thus two exposures of 90 hours each caused more damage than one exposure of this length, but less than a continuous exposure of 180 hours.

Experimental Results.

The experiments carried out on this question are set out in Tables VIII and IX. In Table VIII the first experiment and the last two would appear to indicate that repeated freezings and thawings several degrees above the critical

TABLE VIII. *Repeated freezing and thawing.*

Year.	*Date.*	*Species.*	*Frozen at.*	*Usual CT.*	*Damage percentage for Number of Freezings.* 1.	2.	3.	4.	5.
1932	23–5 Nov.	Sitka spruce	25° F.	13–16° F.	0	0	0	0	0
1932	5–9 Feb.	,,	16° F.	11–15° F.	0	10	20	30	40
1932	5–9 May	Douglas fir and Eur. larch	28° F.	25–6° F.	0	0	0	0	0
1933	31 May–2 June	Scots pine	27° F.	23° F.	0	0	0	0	0

CT.= Critical Temperature.

temperature are unlikely to do any damage. The second experiment gives a clear indication that if temperatures immediately above the critical temperature are used, the amount of damage increases with the number of freezings. The experiments set out in Table IX are rather more complex. In both cases

TABLE IX. *Repeated freezing and thawing.*

Year.	*Date.*	*Species.*	*Frozen at.*	*Usual CT.*	*Damage percentage for Total period of freezing.* 12	6	6	6	6 hrs.
					Period of each freezing. 12	6	2	1	½ hrs.
1933	20 Jan.	Scots pine	14° F.	13–18° F.	15	15	29	29	63
1933	2 May	Eur. larch	23° F.	22–5° F.	25	6	19	12	31

CT. = Critical Temperature.

the highest percentage damage was shown by plants exposed to a total period of 6 hours freezing in ½-hour periods, i.e. they were subjected to 12 separate freezings, each of ½-hour's duration, separated by equal periods at room temperature. Six of 1 hour's duration or 3 freezings of 2 hours' duration give less striking damage, but in both experiments they are worse than 1 freezing of 6 hours. In one experiment continuous freezing for 12 hours has, as might be expected from the experiments described in the last section, no greater effect than freezing for 6 hours, and less than repeated freezings for shorter periods. In the second experiment the 12-hour freezing occupies an unexpected position, being worse than any treatment except the 12 freezings of ½-hour each. We

have already seen that both freezing and thawing usually increase the damage due to low temperature, and that after a short exposure increase of time is not normally accompanied by a corresponding increase in damage. It would, therefore, seem almost certain that repeated freezing and thawing would be more damaging than continuous exposure to low temperature. There is sufficient evidence to indicate that this is usually the case, but further experiments on this point are needed.

The Time of Day at which Frosts occur.

The lowest temperature experienced during a frost may occur at any time of day, but normally during the darker hours between 4 p.m. and 9 a.m. Within this period the bulk of the minima occur in the early morning. Analysis of temperature records taken at Oxford, and in Bagley Wood, near Oxford, for the months of January to June 1934–7 indicates that about 70 per cent. of the minima occur between 4 a.m. and 8 a.m. Thus in nature, although there is a wide variation in the time of occurrence of frost minima, they do usually occur in the early morning. The metabolic activity, and therefore the state of the cell contents of a plant, varies throughout each 24 hours and as we have already seen this might affect frost-damage. The authors' experiments on other aspects of frost-damage have been carried out regardless of time of day, and it is therefore important to know whether this factor was exercising any influence on the results. Very little work has been done on this aspect of frost-damage. McCool and Millar (17) found that depression of the freezing-point in cereal tissues was least in the early morning and greatest at midday, which might indicate that the hardiness of the plant increased during the morning and decreased during the evening and night. Salmon (23), working on the winter-hardiness of wheat and rye, says that comparative experiments must be carried out at the same time of day.

Only two experiments on this matter have been carried out by the authors. The first was on 24 and 25 January 1933, using Scots pine and a temperature of 12° F., the second on 3 and 4 May of the same year, with European larch and a temperature of 23° F. In each instance groups of trees were frozen every 4 hours throughout a complete 24 hours: in neither was there any significant difference between lots frozen at different time of day. It would seem that, at any rate with conifers, the time of day at which freezing takes place is of no importance.

(To be concluded)

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FIG. 1

FIG. 2

FIG. 3

FIG. 4

PLATE I

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EXPLANATION OF PLATE

Fig. 1. Norway spruce, late-flushing variety, frozen at 23° F. on 24 May 1934. Treated for 5 days before freezing as follows: left to right, 1–3 refrigerator at 33° F., 4–6 outdoors, 7–9 incubator at 70° F. (Photographed July 1934.)

Fig. 2. European larch, frozen at 9° F. on 9 February 1932. Treated for 4 days before freezing as follows: left to right, incubator at 81° F., incubator at 68° F., alternate days at 80° F., and 39° F., laboratory at 51–7° F., outdoors at 30–40° F., and refrigerator at 39° F. (Photographed June 1934.)

Fig. 3. Scots pine, frozen at 18° F., on 18–19 March 1933. Left to right, 1–3 slowly thawed, 4–6 quickly thawed. (Photographed July 1933.)

Fig. 4. European larch, frozen at 10° F. on 23 March 1935. Left to right, 1–3 slowly frozen and slowly thawed, 4–6 slowly frozen and quickly thawed, 7–9 quickly frozen and slowly thawed, 10–12 quickly frozen and quickly thawed. (Photographed August 1935.)

Note: In all these figures the plants photographed were not the whole number used, but merely a typical selection from each treatment.

RHIZOPOGON LUTEOLUS, A MYCORRHIZAL FUNGUS OF *PINUS*

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FOR some years *Rhizopogon luteolus* Fr. et Nodh. has in Australia been suspected of being the fruiting body of a mycorrhiza-forming fungus of *Pinus* sp., Kessell (2) in Western Australia in 1927 drawing attention to the association of sporophores of this fungus with various species of *Pinus*, and since then the same association has often been noted. However, it was not until May 1936 that the organism was known to be present in Queensland plantations, when it was found fruiting abundantly in association with *Boletus granulatus* at Beerwah and Glasshouse Mountains. The Association of the two fungi under the same trees was noteworthy, and it is thought possible that both species are symbionts on the same trees at the same time. The species of *Pinus* noted in the association were *P. taeda* and *P. caribaea*.

In 1935 *Rhizopogon luteolus* was found fruiting in nursery-beds containing seedlings of *P. radiata*, *P. taeda*, and *P. caribaea* at Banyabba in Northern New South Wales, but no evidence of the presence of *Boletus granulatus* was found there or elsewhere in the district. Specimens were collected and isolations made by the author by opening the sporophores under aseptic conditions and placing pieces of the sporophore on potato dextrose agar plates with a pH of 5. In this way a pure culture of the organism was obtained. Seed of *P. taeda* and *P. caribaea* was sterilized for 3 minutes in 1 : 1,000 mercuric chloride solution and sown in sterile soil in sterilized root observation boxes (1, 3). The soil mixture used consisted of 2 parts of white sand, 1 part of loam, and 1 part of leaf-mould, this mixture having been found to be very satisfactory for root studies. The seed was sown quickly so as to quickly obtain a thick network of roots in the boxes and against the glass. When satisfactory growth was obtained, which was 8 months from sowing, the root systems were inoculated with a pure culture of *Rhizopogon luteolus*. Young actively growing cultures in petri dishes were prepared, and then, removing the cover and glass wall from one side of a root observation box, inoculations were made at several points (usually 6) on the soil surface amongst the roots, aseptic precautions being observed. The glass was replaced, and the points of inoculation were marked by colouring the glass above those spots with methyl violet.

In a few days strands of mycelium were seen radiating from the points of inoculation and enveloping the short roots of the pines, and typical mycorrhizae were developed, not differing in general appearance from those formed by *Boletus granulatus* (3). The mycelium then spread gradually over the whole side of the box and some weeks later appeared on the uninoculated side, having progressed thither through the soil. On inspection 3 months after inoculation

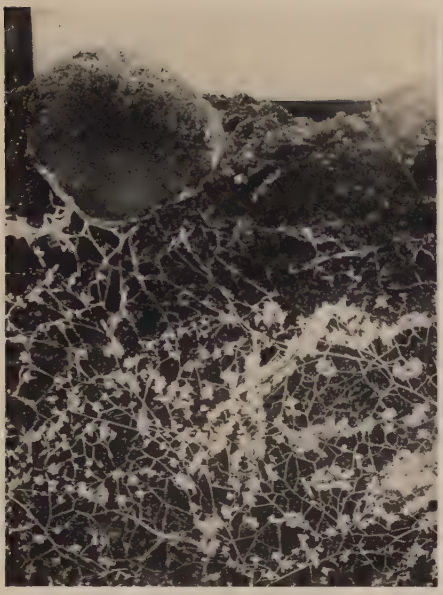

FIG. 1. Sporophore and mycorhizae formed after artificial inoculation of roots of *Pinus taeda* with a pure culture of *Rhizopogon luteolus Fr.*

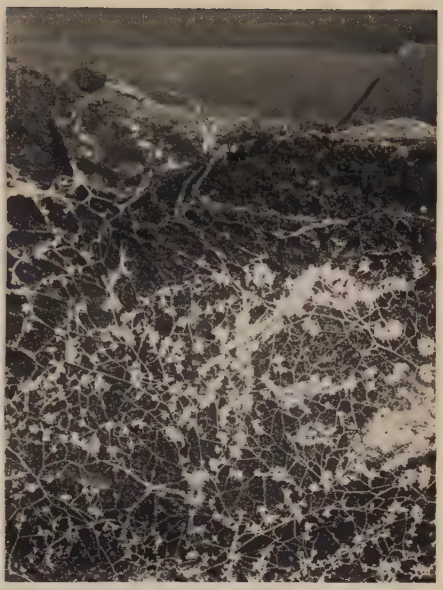

FIG. 2. Degeneration of sporophore of *Rhizopogon luteolus Fr.* shown in Fig. 1.

FIG. 3. Root-observation box containing sterile plants of *Pinus taeda* artificially inoculated with *Rhizopogon luteolus* showing development of mycorhizae and hypogeal sporophores. Scale in inches

PLATE II

it was interesting to note that a sporophore of *Rhizopogon luteolus* had developed on the surface of the soil in one of the boxes (Plate II, fig. 1), thus completing the cycle of the organism which was isolated from a sporophore introduced to healthy pine roots and later fruited, producing a sporophore again. Within 2 weeks sporophores were found in all the boxes in all stages of development. But it is worthy of note that in no further cases were the sporophores epigeal, all later fructifications being hypogeal (Plate II, fig. 3). Subterranean fructifications have also been found under plantation conditions in several instances on *Pinus taeda*. All fructifications were produced from regions of actively spreading hyphae, and none from the mature brown mycorrhizae. The browning of the mycorrhizae within a few days of the infection of the roots with the snow-white mycelium was very noticeable. The fructifications lasted on an average 5 days before breaking down to a slimy viscid mass (Plate II, fig. 2). It is considered possible that earthworms, beetle larvae, &c., help in the spread of the spores by distributing them through the soil during their tunnelling operations. Strands of mycelium could easily be followed from the sporophores to the mycorrhizae on the pine roots.

It is now proposed to plant the inoculated seedlings out in the field in isolated plots. Seedlings infected with *Boletus granulatus* and obtained in a similar manner will also be set out, and if possible comparisons in the growth of the trees infected with each of the respective organisms made.

SUMMARY.

Rhizopogon luteolus has been found in association with species of conifers in Australia. It has also been found fruiting with *Boletus granulatus* under the same tree in Queensland.

Pure cultures of *Rhizopogon luteolus* were isolated, and with it the roots of sterile seedlings of *P. caribaea* and *P. taeda* were inoculated.

Mycorrhizae were quickly formed spreading from the points of inoculation.

A sporophore developed on the soil surface in one instance. In others sporophores developed below the soil surface.

All sporophores were produced in regions of actively developing hyphae, none from mature mycorrhizae.

The sporophores broke down after an average of 5 days to a slimy viscid mass.

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THE KILN-STERILIZATION OF TIMBER INFESTED BY *LYCTUS* POWDER-POST BEETLES

BY E. A. PARKIN

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THE *Lyctus* powder-post beetles are a group of wood-boring insects which attack the sapwood only of certain recently seasoned hardwoods and have for many years past been causing considerable losses to the hardwood-using industries in Great Britain and other countries. The life-history, habits, and economic importance of these insects, together with recommendations for the prevention and control of their attack, have been described in this country by Altson (1) and Munro (4) and, more recently, as a result of investigations at the Forest Products Research Laboratory, by Fisher (2, 3) and Parkin (5).

Very few hardwood timber firms take active steps to prevent *Lyctus* damage, but the majority are, at some time, compelled to consider methods of control: sterilization of infected timber in a steam-operated kiln is one of the most satisfactory.

Reference to previous research on kiln-sterilization in relation to *Lyctus* control reveals that three papers only are of special interest. Snyder (6), in some preliminary experiments, showed that a temperature of 180° F. in a dry kiln must be maintained for at least ½ hour in order to kill all stages of *Lyctus* in the wood. This temperature, however, was deleterious to the timber and impaired its strength. Snyder and St. George (7), therefore, carried out a series of experiments at lower temperatures in a saturated atmosphere, from which they concluded that 'Temperatures of 130° F. and upward, maintained for 1½ hours, or longer, are fatal to these insects if all parts of the wood infested by them have at the beginning of the exposure to these temperatures been brought to the minimum temperature of 130° F.' Fisher (2) has repeated and extended this work and lays particular stress on the time required to overcome the lag of penetration of heat into the timber after the kiln atmosphere has reached the desired temperature. He has determined that all stages of *Lyctus* can be killed in timber 1 inch in thickness by exposing the wood to a temperature of 130° F., at a relative humidity of 100 per cent., for 2½ hours, a proportionately longer time being necessary for greater thicknesses. This schedule has been generally accepted in this country as the standard and has been successfully employed commercially during the past 8 years. A number of firms, however, possess chambers in which the conditions mentioned cannot easily be attained, but which would be suitable for the sterilization of infested timber if slightly lower temperatures and humidities, held over a longer period, could be used. Fisher points out that there are indications from the results of his experiments that, provided the temperature does not fall below

120° F., prolonged treatment at 60–70 per cent. relative humidity would suffice to kill *Lyctus* and sterilize infested timber. A series of experiments was, therefore, planned to extend this work by determining what periods of exposure would be necessary to ensure sterilization of timber infested by *Lyctus* powder-post beetles at relatively low temperatures (105–125° F.) and humidities (60 and 80 per cent.). An account of these experiments is given in this paper.

MATERIAL.

American ash, infested probably by *Lyctus planicollis* Le C., was used when available, since this timber is easier to cut up for examination than English oak (attacked by *L. brunneus* Steph.) or French walnut (*L. brunneus*), which were utilized when the supplies of ash ran short. The dimensions of the samples were $6 \times 3 \times 1$ in., but slightly larger pieces of the same thickness (1 in.) were used if the wood was not heavily infested.

The work has been carried out during the period December 1933 to January 1936 and has been confined to the winter months in order that half to fully grown larvae should be present in the samples. Larvae only have been used during these experiments since they are present in wood all the year round, whereas other stages are seasonal in occurrence. However, from earlier experiments (unpublished) it is known that eggs of *L. brunneus* and *L. linearis* are killed by exposure for 3 minutes to 130° F. and 95 per cent. relative humidity, and are therefore much less resistant than the larvae. Moreover, Fisher (2) indicates that conditions suitable for sterilizing timber containing larvae will also kill pupae and adults.

METHOD.

The experiments were carried out, with the co-operation of the Seasoning Section of the Laboratory, in a model kiln in which the desired conditions were held constant to within ± 1° F. and ± 2 per cent. relative humidity over long periods. The kiln was heated to the required conditions and the batch of samples then introduced on a rack. This rack consisted of a series of wires extending horizontally across a wooden framework in such a way that the samples could be laid upon the wires with sufficient space between to permit free circulation of air around them. During the run, the wet and dry bulb temperatures were read every 3 hours or less according to the period of exposure. This period was timed from the moment the samples were placed in the kiln, and therefore includes the time required for the wood to attain a temperature equal to that of the surrounding atmosphere.

Sets of 3 samples were withdrawn at predetermined intervals throughout the run. The samples were removed to the laboratory, where 2 of each set were chopped up for examination as soon as possible after treatment: the third was kept for about a month before examination in case the larvae might be able to recover more satisfactorily when left in the wood.

Larvae cut out of the samples were kept in corked tubes in the laboratory

and examined periodically until they could be classified as alive or dead. A larva was considered to be alive if it was able to perform any muscular movement, however slight, although in many cases the insects would probably never have recovered sufficiently to resume feeding and development. Partial recovery was usually evident within a week of treatment, but in a few cases signs of life were not detected for 2 to 4 weeks. Larvae could not be classified as dead until signs of post-mortem changes were apparent, and it was often necessary to keep the insects under observation for several weeks before such changes were discernible.

Control samples from the same supply of wood as the experimental specimens were cut up from time to time in order to ensure that living larvae were present before treatment.

RESULTS.

In Table I the results of all the experiments have been combined in such a way as to show the percentage kill of larvae for different periods of exposure to various temperatures and relative humidities.

From the results given in Table I, the approximate minimum lethal periods for the various combinations of temperature and relative humidity may be extracted (Table II).

It will be seen that a reduction in relative humidity necessitates an increase in the period of exposure in order to achieve a 100 per cent. kill. This holds for all temperatures except 110° F., where the lethal period at 60 per cent. R.H. is less than at 80 per cent. R.H. If the lethal periods are plotted against the corresponding temperatures for the two relative humidities, it is found that a smooth curve can be drawn through the points obtained at 80 per cent. R.H. and a curve of similar shape will pass through 4 of the 5 points obtained at 60 per cent. R.H. According to the curve, the lethal period at a temperature of 110° F. and 60 per cent. R.H. should be about 102 hours, instead of 84 hours as recorded. No reason can be advanced to account for this anomalous result, which has been checked by a second series of experiments.

Although samples were sterilized successfully at 105° F., the period of exposure is rather long for commercial practice and there is a danger that the variation in temperature in a kiln might allow part of a load to pass through without reaching a lethal temperature. The use of a temperature as low as 105° F. is, therefore, not recommended, nor, owing to the anomaly in the results, is 110° F.

Effective sterilization may be carried out at temperatures of 115–25° F., provided that an adequate margin of safety is allowed on the periods of exposure given in Table II.

As mentioned earlier, during the experimental kiln runs the samples were introduced into the chamber after it had attained the desired conditions. This is not possible in commercial practice owing to the time required to load the kiln, so that the period of exposure must be calculated from the time at which the atmosphere in the loaded kiln reaches the required temperature and

TABLE I. *Percentage kill of* Lyctus *larvae in timber after exposure to different kiln-sterilization treatments.*

A. Results of experiments at 80 per cent. relative humidity.

Temperature, ° *F.*	*Period of exposure, hrs.*	*Number of experiments.*	*Number of larvae.*		*Mortality per cent.*
			Dead.	*Alive.*	
105	24	1	3	32	8·6
	48	1	16	38	29·6
	72	1	37	37	50·0
	96	1	76	4	95·0
	120	1	68	1	98·6
	144	2	80	0	100·0
	168	1	71	0	100·0
110	12	1	4	36	10·0
	18	1	64	16	80·0
	24	3	85	34	71·5
	30	2	51	28	64·6
	36	3	97	44	68·8
	48	3	252	5	98·1
	60	4	305	7	97·8
	66	1	112	0	100·0
	72	2	174	3	98·3
	78	1	99	0	100·0
	84	2	96	4	96·0
	90	1	68	0	100·0
	96	1	50	0	100·0
	108	1	56	0	100·0
115	6	1	46	22	67·7
	9	1	41	3	93·3
	12	3	79	78	50·3
	18	3	99	8	92·5
	24	3	99	2	98·0
	30	2	52	0	100·0
	36	1	37	0	100·0
	42	1	42	0	100·0
120	2	1	53	2	96·4
	4	1	30	1	96·8
	5	1	34	2	94·5
	6	1	39	0	100·0
	8	1	41	0	100·0
125	1	1	46	16	74·2
	1·5	1	26	3	89·7
	2	1	25	0	100·0
	4	1	40	0	100·0
	8	1	47	0	100·0

B. Results of experiments at 60 per cent. relative humidity.

Temperature, ° *F.*	*Period of exposure, hrs.*	*Number of experiments.*	*Number of larvae.*		*Mortality per cent.*
			Dead.	*Alive.*	
105	96	2	61	11	84·7
	120	2	68	14	82·9
	144	2	51	2	96·3
	168	2	78	0	100·0
	192	1	16	0	100·0
110	18	1	4	16	20·0
	24	1	12	15	44·4
	30	1	49	12	80·3
	36	1	24	15	61·5
	48	1	27	3	90·0
	60	2	77	5	93·9
	72	1	35	2	94·7
	84	2	128	0	100·0
	90	1	107	0	100·0
	96	1	120	0	100·0
	102	1	134	0	100·0
	108	1	79	0	100·0
	114	1	61	0	100·0
115	9	1	0	20	0·0
	12	1	21	12	63·6
	18	1	33	17	66·0
	24	2	77	7	91·7
	30	1	34	1	97·2
	36	2	53	0	100·0
	42	1	27	0	100·0
120	3	1	17	6	73·9
	5	1	52	7	88·2
	6	1	24	12	66·7
	7	1	73	0	100·0
	10	1	45	0	100·0
125	1	1	16	31	34·1
	2	1	42	39	51·8
	3	1	31	1	96·8
	4	1	47	0	100·0
	8	1	36	0	100·0

humidity. An allowance must be made for the time necessary for the heat to penetrate to the centre of the boards after the surface has come into approximate equilibrium with the kiln atmosphere. During the experimental work this allowance was included in the lethal period, but, because oft he smallness of the samples, the lag in penetration would probably not be so great as in the case of commercial stock. In order to be quite safe, therefore, there should be

added to the lethal period the full allowances (time required to overcome lag) given by Fisher (2) in his table, which shows the periods of exposure necessary for the destruction of all stages of *Lyctus* powder-post beetles in timber 1–3 in. thick at a temperature of 130° F. and relative humidity of 100 per cent. and which is reprinted below with very slight modifications (Table III).

TABLE II. *Approximate lethal periods for* Lyctus *larvae in timber at various temperatures and relative humidities.*

Relative humidity.	*Temperature, ° F.*	*Lethal period, hours.*
80 per cent.	105	144
	110	90
	115	30
	120	6
	125	2
60 „	105	168
	110	84
	115	36
	120	7
	125	4

TABLE III. *Periods of exposure necessary for sterilization of* Lyctus-*infested timber of different thicknesses at* 130° F. *and* 100 *per cent. R.H.*

Thickness of timber, inches.	*Time required to overcome lag, hours.*	*Lethal period, hours.*	*Safety factor, hours.*	*Total period of exposure after kiln has attained required conditions, hours.*
1	½	1½	½	2½
2	2	1½	½	4
2½	3½	1½	½	5½
3	4½	1½	½	6½

For the treatment of 1-inch boards, the periods of exposure in the kiln for temperatures of 115° F., 120° F., and 125° F., and relative humidities of 80 per cent. and 60 per cent., are shown in Table IV. The safety factor has been arbitrarily fixed at 25 per cent. of the experimentally determined lethal period for the larvae.

For timber less than 1 inch in thickness the same treatment as for 1 inch should be given. When the load contains boards more than 1 inch thick, the time required to overcome the lag in penetration of heat into the wood must be increased in accordance with the figures shown in Table III. Thus the total sterilization period which should elapse after the kiln has reached conditions of, for example, 120° F. and 80 per cent. relative humidity for boards 3 inches thick would be $4\frac{1}{2}+6+1\frac{1}{2} = 12$ hours.

Although the use of a relative humidity of 100 per cent. helps to bring about the more rapid death of *Lyctus* larvae in wood, kiln-sterilization at relative humidities less than 100 per cent. is advantageous in that, providing a suitable humidity is chosen, the timber does not change its moisture content by any appreciable amount even during long periods of exposure, nor does it suffer from surface wetting due to condensation.

TABLE IV. *Periods of exposure necessary for sterilization of* Lyctus-*infested timber* 1 *inch in thickness.*

Relative humidity, per cent.	*Temperature, ° F.*	*Time required to overcome lag, hours.*	*Lethal period, hours.*	*Safety factor, hours.*	*Total period of exposure after kiln has attained required conditions, hours.*
80	115	½	30	7½	38
80	120	½	6	1½	8
80	125	½	2	½	3
60	115	½	36	9	45½
60	120	½	7	2	9½
60	125	½	4	1	5½

It must be emphasized that kiln-sterilization does not render timber immune from subsequent reinfestation, and, since there is at present no commercially practicable method of achieving this, kiln-sterilized stock should be segregated or, preferably, should be utilized with as little delay as possible, for the finished article is usually protected to some extent against infestation by the polish or varnish. Apart from its application to stocks of converted timber, the treatment can also be utilized for the control of *Lyctus* in manufactured articles, whether constructed of solid wood or plywood, although care must be taken to adjust the humidity of the kiln atmosphere so that the change in moisture content of the furniture, panelling, &c., is kept at a minimum. Care must also be taken to ensure that joints do not fail because of softening of the glue.

SUMMARY.

The results of this investigation show that it is possible to use lower temperatures and relative humidities than have hitherto been recommended for the sterilization of timber infested by *Lyctus* powder-post beetles. Timber can be sterilized at a temperature as low as 105° F. and a relative humidity of 60 per cent., but it is recommended that, in practice, a temperature not lower than 115° F. should be employed.

Tables are included showing the periods of exposure which are necessary to kill *Lyctus* larvae in timber of different thicknesses at temperatures between 115° F. and 130° F. and relative humidities between 60 per cent. and 100 per cent.

ACKNOWLEDGEMENTS.

The author wishes to express his thanks to Mr. W. A. Robertson, Director of Forest Products Research, Department of Scientific and Industrial Research, for permission to publish this paper, and, in particular, to Mr. E. C. Harris, Junior Technical Assistant in the Entomology Section, who carried out much of the routine work of chopping up samples and keeping larvae under observation after treatment.

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THE EFFECT OF SAP-STAIN ON THE PROPERTIES OF TIMBER

I. *Effect of Sap-stain on the Strength of Scots pine Sapwood*

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INTRODUCTION.

IT has generally been stated that the blue stain caused by the growth of certain Ascomycetes in the sapwood of coniferous timber has practically no effect on its strength properties. Numerous tests have been made by different workers with somewhat variable results, owing possibly to lack of accurate control of the moisture content of the test-pieces. Rudeloff (5) found the compressive strength of blued wood was slightly higher than that of normal sapwood while the cleavage strength was lower, but these differences were probably not significant. Von Schrenk (6) concluded that for practical purposes stained wood is as strong as the unstained, noting that blued wood showed a greater resistance to splitting along a tangential plane than unaffected wood. Münch (4) as a result of a series of tests concluded that neither specific gravity nor compressive strength are altered as a result of blueing. Weiss and Barnum (7) after testing stained and unstained pieces of Longleaf and of Shortleaf pine (*Pinus palustris* and *Pinus echinata*, resp.) came to the conclusion that for all practical purposes blued wood is as strong as unstained. The heavily stained sapwood of Shortleaf pine was found to be practically equal in bending strength and stiffness to the clear timber but slightly lower in toughness and in surface hardness. Mayer-Wegelin, Brunn, and Loos (3) made a series of comparative tests on the crushing strength of timber from trees which had died standing and become blue-stained and from sound trees, and they came to the conclusion that the staining had not affected the compressive strength of the wood. The present series of tests was undertaken to determine definitely whether infection of the sapwood of Scots pine by a staining organism had any effect on its various strength properties.

SCOPE OF TESTS.

Two entirely distinct series of tests have been made. In the first series all the test-pieces were artificially infected. Two methods of procedure were adopted: (*a*) in which the samples were sterilized by steaming previous to infection with pure cultures; (*b*) in which unsterilized specimens, after infection, were placed in damp chambers, infection by other organisms being allowed to occur also. The results of these tests enabled a comparison to be made of the effects of blue stain on the properties of steamed and of fresh wood. The second series of tests was carried out on material cut from unsterilized planks which had become stained naturally during kiln treatment.

Parallel control tests were also made on clear material from the same trees, subjected to similar treatment, but which had previously been dipped in antiseptic solutions for the prevention of sap-stain.

The effects of sap-stain on the following strength properties were investigated:

1. Toughness.
2. Compressive strength along the grain.
3. Hardness, as measured by resistance to indentation.
4. Strength as a beam under gradually applied loads.
5. Stiffness as a beam, as measured by the stiffness coefficient.

In addition the specific gravity of blued wood has been compared with that of clean wood. Specific gravity in this paper is taken as the value of the ratio

$$\frac{\text{Oven dry weight (gramme)}}{\text{Volume at test (in c.c.)}}$$

SERIES I. TESTS ON ARTIFICIALLY INFECTED SAMPLES.

Strength Properties Investigated.

For the first series of tests the effects of sap-stain on the toughness and compressive strength along the grain were investigated in addition to specific gravity.

Toughness.

A clear, straight-grained specimen, 10 inches long and $\frac{5}{8}$ inch square, freely supported near the ends, was broken by a single blow applied at the centre of the span by a machine of the pendulum type. The energy absorbed in fracturing the test-piece was taken as a measure of the toughness of the timber. For the sake of uniformity, the blow in every case was delivered on a radial face of the specimen.

Compressive Strength along the Grain.

The compressive strength along the grain was determined from a clear, straight-grained specimen 4 inches long and 1 inch square, maximum crushing strength only being found.

Material for test.

All the material for this series was obtained from the sapwood of a freshly felled tree of Scots pine (*Pinus silvestris*), specially selected for straightness of grain and freedom from knots and other defects.

Selection and Preparation of Test-pieces.

(*a*) *Infected after sterilization with pure cultures.* Eight matched groups, both of toughness and of compression test-pieces, were prepared. This number of groups provided for controls (as cut), sterilized controls, and three groups,

to be tested after appropriate intervals of incubation, for each of the two fungi used for infection.

The selection of the specimens for treatment was carried out on the principle of the Latin square (Fig. 1). Each group consisted of 24 specimens obtained from 8 adjacent short bolts (12 inches long for toughness tests and 6 inches long for compression tests) of the tree, marked A to H consecutively. A line scribed down the tree previous to cross-cutting ensured the correct orientation of the separate bolts after cutting. The outer zone of the upper face of each bolt was divided into 24 approximately equal sections numbered 1–24 in a clockwise direction starting from the scribed line. Each of these sections provided one test-piece marked with the number and the bolt letter. There were thus 192 test-pieces marked 1A, 2A . . . 24A (1B . . . 24B), &c.

The allocation of the test-pieces for the different groups was made on the basis of the scheme shown diagrammatically in Fig. 1, in which the position of a test-piece round the periphery is shown in the rows, and the position in the tree (or bolt letter) in the columns. The eight groups are denoted by the markings C (control), CS (control sterilized), 1, 2, 3, 4, 5, 6, for the infected groups. It will be noted that in each block of 64 (8×8) test-pieces (as indicated by the double lines), each group is represented once (and once only) in each row and also in each column. Thus, while the arrangement is a random one to some extent, it is restricted by these conditions, and, using the methods developed for the statistical analysis of such arrangements, a comparison can be made between any two groups in which the variations due to position both in bolts and round the tree are eliminated.

(*b*) *Infected without sterilization.* Only four groups of test-pieces were prepared for this test, to provide one control group and three stained groups to be tested after appropriate intervals of time. The number in each group was again 24 and the arrangement was similar to that described above, except that the number of bolts (columns) was only 4 and each group was, therefore, represented once in each row and once in each column of a 4×4 block, 6 of such blocks being used altogether.

Sterilization and Infection.

The samples resting on damp cotton-wool in large tubes were sterilized by steaming at atmospheric pressure for 30 minutes on each of 3 consecutive days. Two organisms known to cause stain in the sapwood of pine were used. The first, *Ceratostomella coerulea* (*Ophiostoma coerulea*), had been isolated from naturally stained pine and the second, which is referred to as S 51, as it has not yet been identified, was isolated from the heavily stained sapwood of Slash pine (*Pinus caribaea*).

The long samples for the toughness tests were infected by pouring over them a suspension of the conidia of the staining fungus. The short samples for the compression tests were infected by laying them on active cultures of the staining fungi growing on 2 per cent. malt agar in special flasks in the manner described in a previous report (1). The tubes and flasks containing

SERIES I. *Toughness and Compression Parallel to Grain—Artificial Infection.*

No. in periphery.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*
Bolt A . .	C	4	1	3	6	5	CS	2	1	5	3	6	2	4	C	CS	5	1	C	2	3	CS	4	6
„ B . .	2	CS	6	C	4	1	3	5	4	2	CS	1	C	6	5	3	3	6	4	CS	5	2	1	C
„ C . .	1	5	3	6	2	4	C	CS	6	C	5	4	CS	3	2	1	CS	3	2	5	1	C	6	4
„ D . .	4	2	CS	1	C	6	5	3	5	1	C	2	3	CS	4	6	C	4	1	3	6	5	CS	2
„ E . .	6	C	5	4	CS	3	2	1	3	6	4	CS	5	2	1	C	2	CS	6	C	4	1	3	5
„ F . .	5	1	C	2	3	CS	4	6	CS	3	2	5	1	C	6	4	1	5	3	6	2	4	C	CS
„ G . .	3	6	4	CS	5	2	1	C	C	4	1	3	6	5	CS	2	4	2	CS	1	C	6	5	3
„ H . .	CS	3	2	5	1	C	6	4	2	CS	6	C	4	1	3	5	6	C	5	4	CS	3	2	1

FIG. 1. Layout of Test-pieces.

the test-pieces were then kept in an incubator or constant-temperature room at 22° C. The fungi grew rapidly over the surface of the specimens, but the moisture content of the latter was at first too high to permit the hyphae to penetrate, and it was not until they had dried out considerably that the hyphae penetrated throughout them. In the first batches of test-pieces tested the stain was confined to a layer about 1 mm. deep all round the outside. Thus in these tests the penetration of the stain took place less rapidly than would occur when the moisture content is optimum from the start. The unsterilized samples, infected by pouring over them a suspension of the spores of the above two organisms, were kept in a damp chamber in which the humidity was maintained at over 90 per cent. and the temperature at about 25° C. Secondary infection with other moulds occurred naturally, but no wood-destroying fungi developed.

Testing Procedure.

After the requisite period of incubation had elapsed the test-pieces were removed from the flasks, wiped carefully to remove any superficial mycelium, each one being weighed immediately previous to test. The toughness test-pieces were broken in a Denison Toughness Tester, the angles of swing before and after impact being noted, from which, by the use of appropriate tables, the energy absorbed during fracture was found. One end of the test-piece was cut off as near to the fracture as feasible, weighed at once, and dried to constant weight at a temperature of about 105° C. From these weights the moisture content was calculated. The remainder of the test-piece was reserved for mycological examination. After the maximum crushing strength parallel to the grain of each test-piece had been determined, the whole specimen was weighed and then dried to constant weight for determination of the moisture content. A cross-section of the test-piece taken as near the fracture as possible was examined under a hand lens and the percentage of the total area which was stained, visually estimated. Microscopic examination of the test-pieces showed that few hyphae were present beyond the obviously stained area.

Results of Tests.

The values for specific gravity, toughness, and compressive strength after different periods of staining are given in Tables I–IV together with an approximate average figure for the proportion of stained area, taken over the cross-section as near the failure as possible.

(*a*) *Artificially Infected Specimens.*

The apparent increase in toughness due to sterilization was found on investigation to be insignificant. For each of the two staining fungi a progressive decrease in toughness with period of incubation occurred, the decrease, after about 26 weeks' infection, amounting to about 40 per cent. in the wood stained by *C. coerulea* and about 25 per cent. in the samples less heavily stained by S 51. Statistical analysis showed that all these decreases were significant,

TABLE I. *Toughness.*

Fungus.	*Group.*	*Period of incubation, weeks.*	*Specific gravity.*	*Energy absorbed, inch-pounds.*	*Approximate average of cross area stained, per cent.*
	Control	..	0·408	116	..
	Control sterilized	..	0·412	120	..
Ceratostomella coerulea	3	3	0·414	109	8·0
	4	12	0·413	101	12·0
	6	26	0·407	70	88·0
S 51	1	3	0·412	110	18·0
	2	12	0·409	109	28·0
	5	26	0·405	90	29·0

i.e. they were not chance differences due to selection of the material, but were definite decreases caused by exposure to the staining fungi. This result confirms the results obtained in an earlier preliminary experiment carried out by F. H. Armstrong of the Forest Products Research Laboratory, when a reduction in toughness amounting to 20 per cent. was observed in sterilized samples after exposure to *Ceratostomella coerulea* for 26 weeks.

TABLE II. *Compressive Strength along the Grain.*

Fungus.	*Group.*	*Period of incubation, weeks.*	*Specific gravity.*	*Maximum crushing strength, lb. per sq. inch.*	*Approximate average of cross area stained, per cent.*
	Control	..	0·381	2,890	..
	Control sterilized	..	0·380	2,290	..
Ceratostomella coerulea	1	12	0·383	2,370	17·0
	2	24	0·377	2,330	38·0
	3	31	0·377	2,410	35·0
S 51	4	12	0·383	2,400	19·0
	5	25	0·376	2,380	23·0
	6	31	0·376	2,400	38·0

There was an appreciable and significant drop in maximum crushing strength as the result of sterilization. For some reason, however, at present obscure, the values for the infected specimens were somewhat higher than those for the sterilized controls and the differences between the values for groups 1 and 3, or groups 4 and 6, were found to be insignificant, from which it may be concluded that the effect of the sap-stain on the compressive strength along the grain was nil.

Specific gravity. The changes in specific gravity as a result of sterilization were found to be insignificant. The specific gravities of both the toughness and compression test-pieces for both fungi showed a relatively small decrease of the order of 1–2 per cent. after the longest periods of infection. This decrease, though so small as to be negligible from the practical point of view, was nevertheless found to be statistically significant. It probably resulted from the destruction by the fungi of the stored food materials in the medullary rays, as there was no evidence of any attack on the cell-walls. The amount of starch and similar food materials in the medullary rays probably does not exceed 1–2 per cent. of the dry weight of the wood, so that even if this were all consumed by the staining fungus, and the resulting mycelium which was formed weighed an inappreciable amount, the reduction in specific gravity would not amount to more than the 1–2 per cent. which was found.

(*b*) *Infected without Sterilization.*

TABLE III. *Toughness.*

Group.	*Period of staining, weeks.*	*Specific gravity.*	*Energy absorbed, inch-pounds.*	*Approximate average of cross area stained, per cent.*
Control	..	0·400	111	..
1	7	0·397	97	5·0
2	13	0·396	96	13·0
3	20	0·391	80	22·0

Again there was a progressive decrease in toughness depending on the period of infection. After 7 weeks with only about 5 per cent. of the cross-section stained, there was a significant decrease of about 12 per cent. in the average toughness.

TABLE IV. *Compressive Strength along the Grain.*

Group.	*Period of staining, weeks.*	*Specific gravity.*	*Maximum crushing strength, lb. per sq. inch.*	*Approximate average of cross area stained, per cent.*
Control	..	0·389	2,900	..
1	7	0·385	2,880	6·0
2	13	0·385	2,790	13·0
3	20	0·382	2,780	23·0

After 20 weeks' exposure, with approximately 23 per cent. of the total area stained, the drop in maximum crushing strength amounted to only about 4 per cent. on the controls. Though this decrease was found to be a real one, it was nevertheless so small as to have no practical significance.

Specific gravity. Again there was noted a slight but progressive decrease in specific gravity amounting after 20 weeks' exposure to about 2 per cent.

This decrease, though not sufficiently large to be of practical importance, was again found to be statistically significant.

SERIES II. TESTS ON NATURALLY STAINED SAMPLES.

Experiment 1.

Material for Test.

After an experiment to test the efficacy of various antiseptic dips for preventing stain had been completed, using sticks measuring 24 × 1 × 1 in. of Scots pine sapwood, it was decided to make comparative toughness tests on specimens prepared from the treated, unstained sticks, and from the untreated, badly stained ones. Twenty-four standard toughness samples as described for Series I were accordingly prepared from clear treated sticks and from the most heavily stained parts of the untreated sticks.

The toughness of the specimens was then tested as described above, and the results obtained are tabulated below. The test-pieces were stained more or less

TABLE V. *Toughness Values of Clear and Blue-stained Scots pine.*

Condition of timber.	*No. of test-pieces.*	*Specific gravity.*	*Energy absorbed, inch-pounds.*
Clear, unstained	24	0·469	158
Badly stained	24	0·479	139

uniformly all through, and microscopic examination showed that mycelium was present throughout the stained specimens but was mainly confined to the medullary rays.

Analysis of these results showed that the difference in toughness between the badly stained and the unstained material was probably real. In view of the fact that the specimens were not matched and the number of test-pieces relatively small, it was not considered safe to ascribe this difference to the effects of sap-stain only. Taken in conjunction with other results which have been obtained, however, it is probable that the staining was the cause of the reduction in toughness.

Experiment 2.

Source of Material.

The material used was cut from planks which had been dipped in an antiseptic solution containing 1 per cent. of the sodium salts of chlorinated phenols and from the stained sapwood of untreated planks cut from the same trees. Both dipped and untreated boards had been kept for 4 weeks in a kiln at 27° C. and 95 per cent. relative humidity, during which time the untreated pieces became badly stained while the dipped boards remained free from stain.

Tests.

Comparative tests in toughness and compression along the grain were made on the clear and on the stained material, the test-pieces and testing procedure

being as described for Series I. After completion of the tests, a cross-section was taken from each toughness specimen, as near to the fracture as possible, and the proportion of blue stain over that area visually estimated. The results obtained are tabulated below:

TABLE VI. *Toughness and Compression Values for Clear and Blue-stained Scots pine.*

	Toughness.			*Compression along the grain.*		
Condition.	*No. of tests.*	*Specific gravity.*	*Energy absorbed, inch-pounds.*	*No. of tests.*	*Specific gravity.*	*Maximum crushing strength, lb. per sq. inch.*
Clear unstained	71	0·399	84·1	80	0·391	3,510
Badly stained	91	0·394	76·0	80	0·384	3,450

Although the difference in toughness values for the stained and unstained material is relatively less than that obtained in Experiment 1 of this series, the larger number of tests resulted in greater accuracy of the mean values, and statistical analysis showed that this decrease in toughness was a real one. The difference in compressive strength, on the other hand, was of a much smaller order and was found to be insignificant, in fact it may have been accounted for by the slight difference in specific gravities of the clear and stained material.

The results of the toughness tests were grouped according to the percentage of stained area over the cross-section, and it was found that the loss in toughness was roughly proportional to the extent of the staining, as shown by the following figures:

Percentage area stained.	*Average specific gravity.*	*Average toughness, inch-pounds.*
Nil, i.e. clear	0·399	84·1
0–39	0·392	79·2
40–69	0·388	77·5
70–100	0·400	73·7

Comparison with the data of Table I shows that the loss in toughness relative to the proportion of area stained was considerable greater in those tests than the above. This is due partly to the fact that in Series I the whole test-piece was subjected to the action of the fungus, the first part to be attacked being the outer skin, that is, the most highly stressed part during test. A given percentage of staining confined to this area would produce a much more marked effect on the toughness of the specimen than the same amount of staining nearer the centre. The data of the above table were derived from test-pieces cut from timber already stained, and the incidence of the staining over the cross-section was purely fortuitous and not confined, for lightly stained material, to the surface.

Experiment 3.

Material for Test.

The material used in this experiment was obtained from the same series of treated and untreated planks as was used in Experiment 2, the sapwood of the former being bright and clear, and of the latter badly stained.

Tests.

The properties on which the effects of blue stain were investigated were maximum bending strength, stiffness, and hardness as measured by resistance to indentation.

The test specimen for the bending strength and stiffness tests was 10 inches long and $\frac{5}{8}$ inch square. It was centrally loaded over a span of 8·75 inches, the loading head being brought down at a speed of 0·03 inches per minute. Readings of the deflection at the centre were taken at load increments of 5 lb. up to the maximum load. The load-deflection graphs were plotted to obtain the value of the stiffness, and the maximum bending strength was calculated from the maximum load. The work absorbed up to the maximum load, which provides an indication of the resistance of the timber to suddenly applied loads, was found for each specimen from measurement of the area below the load-deflection graph.

The hardness test-piece was 3 inches long and $\frac{5}{8}$ inch square. A small sub-standard hardness tool was used, since the size of the specimen did not permit of the use of the full-sized standard indentation tool. The hemispherical end of a steel rod 0·222 inch diameter was pressed into the wood under steadily increasing load until it was embedded to a depth of 0·111 inch. An electric-signal circuit was arranged to indicate when the ball was embedded to the requisite depth. The load on the specimen at this point was taken as a measure of the hardness of the timber. Measurements were made on the radial and tangential faces and on the end grain.

The results of tests are given below in Tables VII and VIII.

TABLE VII. *Maximum Bending Strength and Stiffness of Clear and Blue-stained Sapwood of Scots pine.*

Condition.	*No. of tests.*	*Specific gravity.*	*Maximum bending strength, lb. per sq. in.*	*Stiffness coefficient, 1,000 lb. per sq. in.*	*Work to maximum load, inch-lb. per cu. in.*
Treated, unstained	(*a*) 100	0·410	6,270	950	8·0
	(*b*) 40	0·439	6,780	1,130	..
Badly stained	(*a*) 40	0·411	6,180	1,030	7·1
	(*b*) 50	0·462	6,910	1,090	..

Analysis of the results showed that the decrease of about 1 per cent. in maximum bending strength in the group of tests marked (*a*) was insignificant

TABLE VIII. *Side and End Hardness of Clear and Blue-stained Sapwood of Scots pine.*

Condition.	*No. of tests.*	*Specific gravity.*	*Load to produce given indentation.*		
			Radial face, lb.	*Tangential face, lb.*	*End grain, lb.*
Treated, unstained	100	0·405	133	136	134
Badly stained	40	0·405	117	118	115

and might have been due to the natural chance variations in the timber. These specimens were not, of course, as closely matched as those used in Series I, and it is not possible, therefore, to detect small but significant changes, but the results are in general agreement with those for the closely related property of compressive strength along the grain as found for the kiln-infected group of Series I.

The stiffness showed a significant increase for the stained material in the group of tests marked (*a*). In view of the unexpected nature of this finding, repeat bending tests were made on material of similar origin to that of (*a*). The results of these supplementary tests are given in Table VII (*b*). The difference in specific gravity for the stained and for the unstained material indicates that the matching of these repeat groups was not so good as for the originals, and in comparing strength values this difference in specific gravity must be taken into consideration. The equivalent values of the maximum bending strength and stiffness coefficient at an average specific gravity of 0·45 were estimated to be about 6,950 lb. per square inch and $1{,}156 \times 10^3$ lb. per square inch respectively for the unstained material, and 6,720 lb. per square inch and $1{,}057 \times 10^3$ lb. per square inch for the stained material. Analysis showed the difference in bending strength to be insignificant, and the difference in stiffness to be on the borderline of significance. Considering these results in conjunction with those for the first set, it was tentatively concluded that bending strength and stiffness had not been affected to any material extent by the staining of the timber.[1]

The work to maximum load, which is to some extent a measure also of the toughness of the timber, showed a significant decrease of about 11 per cent. This again is in general agreement with the results already found for toughness.

Both side and end hardness showed a significant decrease of the order of 13 per cent. as a result of staining. An exactly similar decrease in hardness was observed by F. H. Armstrong of this Laboratory in a previous preliminary test on Scots pine which had been steamed before exposure to the staining fungi.

[1] A third series of tests on stiffness, for which very closely matched clear and stained test-pieces are being used, is in progress. It is hoped that the results of these tests will provide more definite evidence of the effect of the staining on stiffness.

DISCUSSION AND CONCLUSIONS.

The results obtained in this investigation are in general agreement with the results obtained by previous workers. The presence of blue stain in pine sapwood was found to cause a definite reduction in toughness amounting in one case to as much as 30 per cent. in unsteamed wood, while in wood which had been sterilized by intermittent steaming the fungus seemed to be capable of more vigorous growth, in one instance reducing the toughness by as much as 40 per cent. of the control values. Chapman (2) came to a similar conclusion as a result of comparative tests on the influence of blue stain caused by *Graphium rigidum* and by *Ceratostomella pilifera* on the toughness of pine sapwood; he found that the toughness of unsteamed wood which had become blue-stained was about 70 per cent. of that of the unstained controls, but on the other hand the toughness of wood which had been steamed before exposure to blue-staining organisms was only 50 per cent. of that of the controls. Whether the milder heat treatments commonly employed in kiln drying have any effect on liability of wood to the attack of staining fungi remains to be investigated. It is well known that exposure of wood in a moist condition to high temperatures induces slight incipient hydrolysis of certain constituents of the cell-wall which may render them more liable to decomposition by staining fungi which normally are unable to attack them.

From a practical point of view the results of this investigation may be summarized as follows: The presence of blue stain has no appreciable effect on the compressive strength or on the bending strength, hence blued softwood can safely be used for carcassing work in buildings and for poles, pit props, and so on. The hardness of blued timber is slightly lower than that of normal unstained wood, but this difference would probably not be sufficiently large to affect the wearing quality of timber used for flooring. An appreciable reduction in toughness results from the staining of sapwood, and this reduction may be very much more serious if the wood has previously been steamed. Where a high resistance to impact, i.e. to suddenly applied loads, is required the presence of the stain is undesirable, and blue-stained wood should never be used for the construction of aircraft and similar purposes where a high degree of toughness is an essential quality.

SUMMARY.

1. Experiments are described in which the specific gravity, toughness, compressive strength, bending strength, and hardness of pine sapwood infected with blue stain caused by *Ceratostomella coerulea* or by other similar organisms have been compared with those of clean unstained sapwood. Two series of tests were carried out—the first on matched samples, some of which were sterilized by steaming and in which infection was artificially produced, and the second on samples selected from naturally stained planks.

2. It was found that the presence of the staining fungi had no appreciable effect on the compressive strength, or the bending strength, but that it caused a marked reduction in toughness and also slight reduction in hardness.

3. The effect of the staining fungi on toughness was found to be much greater when the timber had first been sterilized by steaming at 100° for 90 minutes, and in one case the reduction in toughness of the steamed wood resulting from stain amounted to 40 per cent. of the values for unstained controls.

4. Only when timber of exceptional toughness is required should the presence of stain be regarded as deleterious. Blue-stained sapwood should, however, never be used for purposes where timber having a high resistance to suddenly applied loads is required.

ACKNOWLEDGEMENT.

The authors wish to express their thanks to Mr. W. A. Robertson, Director of Forest Products Research (Department of Scientific and Industrial Research), for kindly permitting the publication of this paper.

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THE CLASSIFICATION OF CONIFERAE

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CONIFERS are of so much importance in forestry and arboriculture that a voluminous literature about them has accumulated. The 'flower' of the Gymnosperms, which some systematists now exclude from the 'Flowering Plants', has so few organs that the characters available for defining groups of genera are limited in number, and until very recently the genera of living conifers were all placed in two, or at most three, families.

Intensive study of this interesting and ancient group of Spermaphyta, carried out on morphological, anatomical, and cytological lines, has thrown much light on their affinities, indicating that apparently small differences between the genera are sufficiently constant to be of major taxonomic value; this has led to a complete recast of their classification. There has not yet been time, however, for the changes to become embodied in the literature of forestry and arboriculture, and there seems to be need for a summary of it for the benefit of those foresters and students who are interested in the subject, but who have not access to the publications in which it has been brought out.

In the second edition of *Die Natürlichen Pflanzenfamilien* of Engler and Prantl (Auflage 2, Band 13, pp. 121–403, 1926) Dr. R. Pilger gave a revision which differs materially from that found in the first edition. The monotypic genus *Ginkgo* is no longer included in the Class Coniferae, but is relegated to a Class of its own, the Ginkgoariae, of which it forms the sole Family, the Ginkgoaceae.

These two Classes can be differentiated as follows:

a. Tree irregularly branched: leaves scattered, fan-shaped; nerves forked, resembling those of certain ferns: embryo with 2 cotyledons
Class **Ginkgoariae.**

a. Trees typically with radially symmetrical branching; wood with resin-passages (except in *Taxus*): leaves opposite, whorled or fascicled, simple; nerves parallel, simple: embryo usually with several cotyledons
Class **Coniferae.**

Class CONIFERAE

The Coniferae are divided into two Orders, the Taxales and the Pinales, recognizable by the following characters:

a. Sexes mostly dioecious: flowers solitary, axillary or apparently terminal: stamens peltate: seed mostly solitary, more or less enveloped in a pulpy integument or cupule
Order 1 **Taxales.**

a. Sexes mostly monoecious: flowers catkin-like, or borne in catkins which become cones: stamens not peltate: cones mostly well developed

(berry-like or drupe-like in *Juniperus*), the seeds concealed between scales, often winged Order 2 **Pinales.**

Order 1. TAXALES

Leaves never on spur-shoots: sexes mostly dioecious: cone-formation imperfect in the ♀, the 'cones' generally succulent (never woody), their scales becoming fleshy (or cones not developed); ovules frequently exposed: scales usually few with 1 or 2 ovules each, or the ovule apparently terminal (*Taxus* type): seeds projecting beyond the scales, or even entirely naked, either with one integument, the external part of which is fleshy and the internal hard and stone-like (*Cephalotaxaceae*), or with 2 'integuments' of which the external becomes the fleshy and coloured 'aril' (*Taxaceae*), or the scales below the ovule become fleshy (*Podocarpaceae*): ♂ cones composed (except in *Acmopyle*) of *peltate* stamens (the pollen-sacs on the upper side sometimes aborted).

Key to the Families of Taxales

a. Pollen-sacs 2; pollen-grains usually winged: ovules 1 or 2 in the axils of the uppermost scales on an axillary shoot, the integument united with the scale below (except *Pherosphaera*): seeds with a dry testa (but the sterile scales sometimes fleshy and concrescent into a 'receptacle')
Family 1. **Podocarpaceae.**

a. Pollen-sacs 3–8; pollen-grains not winged, *b.*

b. ♀ 'cone' stalked, of several decussate scales, each with a short axillary shoot bearing 2 ovules; seeds without an 'aril' but integument fleshy: ♂ cones in heads borne in the axils of the leaves of the preceding year: pollen-sacs usually 3 Family 2. **Cephalotaxaceae.**

b. ♀ 'cone' reduced to 1 ovule, apparently terminal on an axis covered with scale-leaves, and projecting from these in the seed-stage: seed with cupular 'aril' Family 3. **Taxaceae.**

Family 1. **Podocarpaceae.** Genera 7: *Acmopyle*, *Dacrydium*, *Microcachrys*, *Pherosphaera*, *Podocarpus*, *Phyllocladus*, *Saxegothea*. Species 100: subtropical, chiefly southern hemisphere, and mountains of the tropics (Indo-Malaya, Africa, South America), New Zealand. *Podocarpus* spp. and *Dacrydium* are exploited commercially.

Family 2. **Cephalotaxaceae.** Genus 1: *Cephalotaxus*. Species 5: India, China, Japan.

Family 3. **Taxaceae.** Genera 3: *Austrotaxus*, *Taxus*, *Torreya*. Species 7: temperate regions. Fossil species occur in the Tertiary of Europe and Alaska.

Order 2. PINALES

Leaves sometimes developed on spur-shoots, otherwise variously arranged: sexes mostly monoecious: distinct ovulate cones are formed which are mostly woody (rarely succulent, e.g. *Juniperus*); the bract-scale (in the axil of which

the ovule occurs in the very young cone) undergoes some modification in the formation of the cone, either by an outgrowth from the base of the ovule, forming a free or connate cone-scale (*Pinaceae*, *Araucariaceae*, *Taxodiaceae*), or by enlargement of the bract-scale in length and thickness behind the apex, forming a peltate scale (*Cupressaceae*); rarely a 'berry-cone' is formed (*Juniperus*): seeds hidden among the scales of the mature cone, often winged; testa woody or leathery; aril 0: stamens not peltate, bearing pollen-sacs only on the lower side.

The four families of Pinales differ from one another partly in the arrangement of the leaves, but chiefly in the greater or less degree of union between the bract-scale and cone-scale and in the position of the ovule (the micropyle being turned upwards or downwards). In the family Pinaceae, the cone-closing scales are the cone-scales, in the other families they are formed either by the two scales united (*Taxodiaceae* and *Araucariaceae*) or by the enlarged bract-scale (*Cupressaceae*).

Key to the Families of Pinales

a. Vegetative leaves and scales of the cone arranged spirally; vegetative leaves of various form, sometimes sub-opposite in Araucariaceae, *b*.

b. Pollen-sacs hanging free from the broadened or swollen apex of the stamen: pollen-grains not winged, *c*.

c. Scales of the cone deciduous; bract-scale linear-lanceolate, arising below the outer face of the enlarged cone-scale, or the cone-scale thin and projecting from the bract-scale as a sheath-like, dentate scale: seeds solitary, mostly winged unequally: pollen-sacs 6 or more, 2-seriate, linear Family 4. **Araucariaceae.**

c. Scales of the cone usually persistent; bract- and cone-scales almost completely coalescent and equal in size, together closing the cone: seeds 3–9 (rarely fewer), winged or not: pollen-sacs 2–9 Family 5. **Taxodiaceae.**

b. Pollen-sacs attached along their whole length to the underside of the stamen, 2, subglobose or oblong: bract- and cone-scales almost completely free from each other, the cone-scale large and generally obscuring the bract-scale; scales of the cone generally persistent (except in *Abies* and *Cedrus*): seeds 2 collateral (rarely 1 ovule arrested), usually winged: pollen-grains winged Family 6. **Pinaceae.**

a. Vegetative leaves opposite and decussate, or whorled, mostly scale-like, but sometimes acicular or subulate (especially in the seedling stage): bract-scales decussate (or 3, 4, 6, or 8 in a whorl), enlarging to a peltate closing-scale in fruit, woody or fused into a 'berry-cone' (*Juniperus*), persistent: seeds 1–5, erect, 2–3-winged, rarely wingless: pollen-grains not winged Family 7. **Cupressaceae.**

Family 4. **Araucariaceae.** Genera 2: *Agathis*, *Araucaria*. Species 32: Malaya, Polynesia, Australia, New Zealand, South America. Exploited for timber and dammar resin.

Family 5. **Taxodiaceae.** Genera 8: *Athrotaxis*, *Cryptomeria*, *Cunninghamia*, *Glyptostrobus*, *Sciadopitys*, *Sequoia*, *Taiwania*, *Taxodium*. Species 14: chiefly North temperate zone; a few in South temperate zone.

Family 6. **Pinaceae.** Genera 9: *Abies*, *Cedrus*, *Keteleeria*, *Larix*, *Picea*, *Pinus*, *Pseudolarix*, *Pseudotsuga*, *Tsuga*. Species 130: North temperate zone. Exploited for timber, rosin, and turpentine.

Family 7. **Cupressaceae.** Genera 15: *Actinostrobus*, *Arceuthos*, *Callitris*, *Callitropsis*, *Chamaecyparis*, *Cupressus*, *Diselma*, *Fokienia*, *Fitzroya*, *Juniperus*, *Libocedrus*, *Tetraclinis*, *Thuja*, *Thujopsis*, *Widdringtonia*. Species 100: chiefly North temperate zone, a few in South temperate zone. Many exploited for timber.

SOCIETY'S AND OTHER NEWS

NOMINATION OF OFFICE-BEARERS AND COUNCILLORS

MEMBERS are reminded that nominations for election of office-bearers and councillors at the Annual General Meeting in 1938 must be in the Secretary's hands by 31 October next. There is no special form of nomination, the only requirement being that the nomination must be in writing and be signed by TWO Professional Members (i.e. Fellows or Associates). As the only function of the nomination is to have the nominee's name placed on the list of candidates, there is no advantage in having the nomination signed by more than two Professional Members nor in having more than one nomination (for the same office) in favour of any candidate.

Nominations are required for the following:

Office-bearers, to hold office for one year: President,[1] Vice-President,[1] Editor of Journal,[1] Business Editor,[1] Secretary and Treasurer, and Auditor.

Councillors, to hold office for two years: THREE (Professional Members). A list of those now in office will be found at the beginning of this number. The retiring office-bearers and Councillors are all eligible for re-election.

THE LATE PROFESSOR A. W. BORTHWICK

IT was with sincere regret that foresters learnt of the death of Professor A. W. Borthwick which took place at Aberdeen on 19 April. For a long period he occupied a unique position in Scottish forestry; he was a pioneer in scientific forestry in this country and brought a trained and well-equipped mind to its service. His personal qualities contributed in no small degree to the regard in which he was held. He had a kindly and lovable nature, but he was not lacking in the old fighting qualities of the Borthwicks, and it was only his indomitable will that enabled him to carry on during the past three years under increasing ill health.

Albert William Borthwick was born on 16 October 1872, and was the third son of the late Mr. W. H. Borthwick, of Crookson and Borthwick Castle. His family could trace its decent through five centuries, and although no one was more modest, he was proud of his ancient lineage. He was educated at Madras College, St. Andrews, where his family was then resident, and at St. Andrews University, where he graduated B.Sc., in natural science, taking first-class honours in botany, physiology, and mathematics. His non-academic interests were boxing and dramatic art. He maintained his connexion with his old university throughout his life and returned from time to time for functions. His last resting-place is in the Abbey Churchyard overlooking St. Andrews Bay. After leaving St. Andrews University, he spent four years at the University of Munich studying forestry. On his return he became associated with the botanical department of Edinburgh University under the late Sir Isaac Bayley Balfour, and was successively lecturer in plant physiology and forest botany; he was also lecturer in forestry at the Edinburgh and East of Scotland College of Agriculture. In 1915 he was appointed Chief Forestry Advisory Officer in the Board of Agriculture for Scotland, and during the war period gave assistance to the Board of Trade Timber Supply Department. On the formation of the Forestry Commission in 1919 he was made Chief Technical Assistant to the Assistant Commissioner for Scotland, and later went

[1] Each must be a Fellow resident in Great Britain.

to London as Chief Research and Education Officer. Professor Borthwick's type of mind was not that which finds its most fruitful field in a government department, and it gave him great pleasure when he was appointed in 1926 to be the first occupant of the chair of forestry in Aberdeen University. Professor Borthwick was a D.Sc. of St. Andrews University, a F.R.S.E., while he was given the O.B.E. for his war services. For a long period he was editor of the *Journal* of the Royal Scottish Arboricultural (now Forestry) Society and was a past president of that society. He was a fellow of this society almost from its formation.

H. M. S.

REVIEWS

Recent Literature on Pruning.

(1) *Åstung.* By Dr. Hans Mayer-Wegelin. M. and H. Schaper, Hanover. 1936.

(2) 'Serieprovning av Redskap för Kvistning av Levande Träd.' *Svenska Skogsvårdo föreningens Tidskrift.* No. 1, Vol. 35, 1937. (In Swedish with an English Summary.)

Reviews by W. H. Guillebaud

(1) A comprehensive publication on pruning has long been badly needed; happily this want is now most adequately met by the book under review.

The work comprises no fewer than 165 pages, apart from the literature references, an indication in itself of the importance and complexity of the subject. The author begins with a very interesting survey of the past history of pruning in central Europe. It was news to the reviewer at least to learn that there had already been two periods of intense activity and interest in pruning, namely, in 1780 to 1800, and again in 1860 to 1900. Both 'waves', as Mayer-Wegelin aptly terms them, died down abruptly and were succeeded by several decades in which pruning was under a cloud. The reasons for the rise and fall of these waves are highly instructive, and provide warnings as to the probable fate of the present revival of interest in pruning unless the forestry world profits adequately by past experience.

The second chapter deals with the natural decay and shedding of dead branches, and this is followed by a full treatment of the problem of occlusion of natural as well as of pruned wounds. The dependence of rate of occlusion upon the method of pruning, rate of radial growth, season of pruning, and other factors is dealt with by the author in a clear and comprehensive manner. Twenty pages are then devoted to a discussion of the available evidence as regards the occurrence of disease resulting from live or dead pruning. It is interesting to note how varied are the reactions of different species. Oak, for example, can be safely pruned as long as the branches are quite small, under $\frac{3}{4}$ inch diameter in the case of slow-growing trees, and under $1\frac{1}{2}$ inches diameter in the case of vigorous, fast-growing trees. Close pruning is the only precaution necessary with such small branches. On the other hand, larger branches, up to about three times the dimensions given above, can also be safely removed provided the cut surfaces are immediately dressed with coal tar or some similar preservative. Larger branches should not be touched owing to the risk of introducing disease.

The close pruning of beech is considered to lead almost inevitably to decay, and this species must either be left unpruned or the offending branches shortened to a stump which can be removed after a lapse of a few years, the interval enabling the tree to form a protective or 'shut-off layer' at the base of the branch.

As regards the conifers, dead pruning, i.e. the removal, flush with the stem, of dead branches, is considered as wholly without risk of introducing disease. Live pruning is another matter. Mayer-Wegelin accepts the evidence that live branches of European larch and Douglas fir can be safely removed; he is not quite happy about Scots pine, though there is little evidence to the contrary, but he has no doubt as to the extreme undesirability of the live pruning of Norway spruce. Example after example is quoted of rot attacking the stem as a result of cutting green branches of this species. A curious

omission here is any reference to the species of wood-destroying fungi concerned; it is possible, though somewhat unlikely, that these have not yet been identified. In any case it seems clear that until we have definite evidence that the removal of live spruce branches in Britain does not lead to disease we cannot afford to run the risk and must confine our spruce-pruning to the removal of completely dead branches.

There is little or no information available as regards Sitka spruce apart from one short reference in the January 1937 issue of the English *Quarterly Journal of Forestry*. Sitka spruce is usually very quick-growing and it may be difficult to resist the temptation to remove some of the lowest live branches. It is a question whether the risk is worth running, having regard to the very serious consequences that would follow if the live-pruned wounds should introduce disease.

After describing the treatment of pruning wounds with preservatives the author proceeds to discuss the effect of pruning upon the increment—this is a particularly interesting and informative section—upon the timber, and also in relation to forest risks such as fire, wind, snow, sun scorch, &c. The various objects of pruning are then considered in detail, most space naturally being given to the question of the improvement of the value of timber as a result of pruning. This takes us up to page 122. The remaining 41 pages of the text are devoted to the practical aspects of pruning, choice of stands, selection of stems, height and number of stems to prune, season of pruning, tools, and methods of pruning, &c. Mayer-Wegelin approves the selection of a relatively small number of the best stems, ranging from 100 to 300 per acre, the number depending on species, quality class, size of stem, and height of pruning. The lower and upper limits of economic pruning are considered to be about 13 feet and 27 feet respectively. There is a useful discussion on the most favourable time of year at which to prune. The author considers that the balance of evidence is in favour of the early spring, before the sap begins to rise. The growing season should be avoided, especially in the case of the hardwoods, also Norway spruce. Spruce provides the only exception to the rule that pruned stems should be marked in a permanent manner; the reason for this exception is that the spruce branches are so persistent, remaining even on the mature trees, that no confusion with unpruned trees is likely to arise. Mayer-Wegelin recommends the saw in preference to any form of edged tools. The type of saw with a curved pointed blade appears to be coming more into favour now in Germany, in preference to the bow saw which was formerly almost universally employed. The author rightly stresses the great importance of early pruning, and it comes therefore as somewhat of a surprise to find that he permits the pruning of stands averaging as much as 20 cm. diameter (6 inches quarter-girth) in the case of spruce and 18 cm. diameter ($5\frac{1}{4}$ inches Q.G.) in the case of Scots pine. It is true that these are the upper limit of size for the better-quality classes, but even so it appears questionable whether such stands have not passed the economic size for pruning.

The last section of the text consists of concise instructions dealing with the pruning of each of the major forest species. A truly imposing bibliography completes the work. Dr. Mayer-Wegelin has collected nearly 400 references to literature and in so doing has placed all students of the subject under a deep obligation to himself. To sum up, this is an indispensable work which is likely to remain for long the standard source of information on forest pruning.

(2) In 1936 the Forestry Societies of Sweden appointed a central committee to test and report upon the various pruning implements at present in use in Sweden and the neighbouring countries. A large number of different implements were sent in, 22 of

which were tested under comparable conditions on Scots pine plantations in central Sweden. Of the 22 implements tested, 8 consisted of saws or of tools mainly intended for sawing, the remainder were edge tools, cutting for the most part on the upward, push stroke, i.e. pruning chisels and the like. All were designed for pole pruning from the ground up to a maximum height of about 20 feet. The various tools selected are all illustrated in this article. In the absence of the pictures it would serve no useful purpose to describe the tools in detail, but an attempt will be made to explain the more important types referred to in the conclusions.

In general, the report pronounces in favour of saws and against edge tools, for pruning of the type with which we are mostly concerned in this country, a conclusion, incidentally, which agrees very well with our own experience in recent years. The committee consider that edge tools are only effective when the branches have partially decayed and so require only a light blow for their complete removal; they are not as suitable as saws for dealing with tough branches which have only recently died, or with coarsely branched types of pine which may have branches over an inch in diameter. The saws tested were of three types: curved saws of the Grecian type (similar to the pattern known in this country as the Lyford Pike); bow saws, with a narrow replaceable blade fixed at the two ends of a curved metal frame; and straight broad-bladed saws either with teeth on both sides or with teeth on one side and a cutting-edge on the back. Each of these types is criticized on certain points, but for all-round use the verdict appears to be in favour of the curved-bladed Grecian pattern of saw with the teeth set to cut on the pull stroke. The reviewer's impression is that the type of curved saw used by the Forestry Commission is equal if not superior to any of those used in the Swedish tests.

Chisels have a definite place in pruning, e.g. for the removal of epicormic branches of oak or Sitka spruce and probably also for cutting small live branches of the poplars and willows. One ingenious form of pruning chisel which received favourable mention in the report is known as Ullén's 'Kvisthyvel'. This has a movable guard plate at the back, held in place by a spring. When pressure is applied the plate slides down, freeing the knife-edge, which can then be forced through the branch base. The guard plate prevents accidental injury to the stem when manipulating the chisel. This tool might well be given a trial in Great Britain.

In addition to the comparative tests of the various tools the committee have some useful advice to give regarding the lengths of poles required. The report states that as a general rule pruning up to a height of 20 feet will involve three operations, each of which will require a different length of pole. The first section will be a length of about 8 feet, requiring the use of a 3-foot pole. The second section, from 8 to 13 feet above ground, requires an 8-foot pole, and the third section, from 13 to 20 feet, a 13-foot pole. In our experience a 13-foot pole is difficult to control satisfactorily, and lack of control inevitably results in faulty pruning.

The question of protecting the eyes of the men who are doing the pruning is also discussed; various types of goggles were tested, but none found satisfactory, and it is considered that the best form of protection is a broad yellow-tinted celluloid eye-shade.

It is difficult to read the data relating to the timing studies without a feeling akin to envy. To be able to prune 50-year-old Scots pine, averaging 5 inches in diameter, to a height of 20 feet in 3 minutes (including walking-time between trees) is something that we could not readily achieve in this country. The speed of the work is presumably due to the fine branching habit of the Scots pine in central Sweden. With our coarser branching type of pine similar pruning would take from two to three times as long.

Against the higher cost of pruning in our more southern latitude, however, the greater rate of diameter growth which we can reasonably expect can be offset.

In conclusion the reviewer would like, on behalf of foresters in this country, to express gratitude to the Swedish forestry societies for conducting this useful investigation.

Some Recent German Papers on Manuring and Weed Control.

(1) 'Forstgartendüngung mit Nitrophoska' (Forest Nursery Manuring with Nitrophoska). By W. Bujakowsky.

(2) 'Basaltgrus — der Nachhaltsdünger armer Sandböden' (Crushed Basalt as a Means of building up a manurial Reserve in poor Sandy Soils). By H. H. Hilf.

(3) 'Natriumchlorat als erprobtes Mittel gegen das Landrohr (*Calamagrostis epigeios*)' (Sodium chlorate as a means of combating *Calamagrostis epigeios*). By E. Hermann.

Forstarchiv, 1937. Heft 6/7.

Reviews by A. B. Stewart

(1) Nitrophoska is a mineral fertilizer containing 12 per cent. nitrogen, 12 per cent. phosphoric acid, 21·5 per cent. potash, and 15–18 per cent. calcium carbonate. The nutrient ingredients are present mainly in a water-soluble form. Observations indicate that the young plant has first of all to develop its roots in the soil before it is in a position to make full use of the added manure. The experimental results obtained indicate that spruce seedlings, for instance, if they require manure, can be manured to greatest advantage in their second year. Spring was found to be the best time for applying nitrophoska and, generally, broad-leaved species showed greater response than conifers.

The properties of the soil, elevation, rainfall, and species to be grown all have a bearing on the dressings to be applied. In the experiments described the following quantities of nitrophoska were found to be very suitable:

	For conifers	*For Broad-leaved Species*
Sandy soils	approx. 1 oz. per sq. yd.	1¾ oz. per sq. yd.
Loams	„ 1¼–1½ oz. per sq. yd.	2–2¼ oz. per sq. yd.

In wetter districts it was found that heavier dressings could be applied with advantage. In soils which had been liberally treated with composts or similar organic manures the effectiveness of the nitrophoska was considerably greater than in soils which were low in humus, and great importance is attached to the value of composts. The application beforehand of a thin surface layer of about ¾-inch compost, over and above the working in of compost into the soil, was found to be of considerable value in increasing the effectiveness of the manuring with nitrophoska.

(2) This paper deals with preliminary results obtained in a series of experiments with crushed basalt, which appears to be a useful means of improvng both the physical and chemical properties of poor, light soils. 'Basaltgrus' or crushed basalt is the crushed, sandy material obtained as a by-product in the quarrying of the rock, and consists of particles of diameter anything up to about 2 mm. Basalt meal is a much finer material about 90 per cent. of which passes a 0·2 mm. sieve. Experiments are meantime being conducted with these substances at different rates, e.g. quantities sufficient to give a surface cover of anything up to about 1 inch, or, where planting is in progress, at

rates of anything from ½ lb. up to 12–14 lb. per plant. The question of cost is discussed, but the experiments are not yet sufficiently far advanced to enable us to decide accurately on the most profitable dressings.

In addition to its beneficial effect on the physical properties of these light soils crushed basalt also supplies a certain amount of lime, magnesia, potash, and soda, as well as a little phosphate. On certain soils a surface cover of as little as $\frac{1}{25}$ inch was found to have a beneficial effect. Areas treated with basalt were found to remain moister in dry spells, and this, incidentally, often meant an increased weed population. From the experiments so far conducted, it has been observed that Canadian poplar, Balsam poplar, White alder, and Birch are species which respond markedly. With Red alder response has been less marked. Scots pine seedlings also respond well and experiments with other species are in progress.

(3) Reference is made in this paper to the need for obtaining some means of controlling this weed in German forests, and an account is given of the results of experiments with sodium chlorate which have been carried out at over a hundred centres in Lower Silesia—a dry region with approximately 20 inches annual rainfall. The properties of sodium chlorate and the precautions to be observed in its use are pointed out. To avoid fire risks it is generally advisable, particularly if the solid is being used, to apply it in rainy or wet weather.

The general conclusions and recommendations for reed destruction may be summarized briefly as follows: If growth is thick the reeds should be cut down before dressing with sodium chlorate, which may be applied either as a solution or in the solid form. It was found that a single dressing at the rate of 3½ oz. per sq. yd. was less effective than either a double treatment of ½ oz. per sq. yd. in spring and ¾ to 1 oz. per sq. yd. in autumn, or a treatment consisting of 3 dressings each at the rate of about ⅓ oz. per sq. yd. at monthly intervals in spring.

The sodium chlorate was found to have no harmful effects on the soil; the effect was indeed, if anything, beneficial. In woods it was found that there was practically no risk of damage resulting from sodium chlorate applied inadvertently to the trees. In plantations it was found that young oak, birch, and beech trees were very resistent to damage by sodium chlorate. Young conifers were more sensitive to chlorate damage and it was found advisable to stop the treatment about 8–12 inches from the plants.

In calculating costs, material and labour were considered. It was found that 1 man could treat 1 hectare in 6 hours and, under German conditions, the total costs amounted to 128 *RM.* per hectare (at par approximately £3 per acre; in this country sodium chlorate is more expensive and the material alone for a 1 oz. per sq. yd. treatment would cost over £6 per acre). This figure refers to application of the sodium chlorate in solid form. When the chlorate was applied in solution the costs were somewhat higher, but still much less than those entailed by cultivation methods.

Similar results were obtained in East Anglia against *Carex arenaria*, but using solutions. There is little doubt that sodium chlorate has possibilities—for example, to keep fire lines clear of weeds—but the cost is at present too high.

RECENT WORK ON THE TAXONOMY OF CONIFERS.

(1) 'Révision du Genre Keteleeria.'

(2) 'Révision du Genre Pseudotsuga.'

(3) 'Révision du Genre Tsuga.'

By F. FLOUS. *Travaux du laboratoire forestier de Toulouse*, vol. iv, 1936.

Reviews by M. Y. ORR

THESE works by Mlle Flous form part of a series of monographs on a group of the Abietineae, and are published under the direction of Professor H. Gaussen of Toulouse. Each purports to be a complete conspectus of the genus named and comprises an historical account and general description of the genus, together with a detailed diagnosis of the component species, as well as keys for their identification, based on both external morphology and leaf anatomy. The synonymy of the different species is fully dealt with in the context, although it is noticed that the nomenclature adopted by Mlle Flous is here and there at variance with the views of other authorities on the subject. In every case, the descriptions of the species are accompanied by illustrations of the vegetative organs, cones, and seeds, all of which have been delineated with a meticulous regard for detail. Diagrams of leaf and stem sections have also been included. Some of the drawings, it may be remarked, have the unintentional effect of calling attention to a similarity of features in certain forms which the author would have us believe are specifically distinct.

Having regard to the magnitude of the task which Mlle Flous has undertaken, it is inevitable that some of her statements, and not a few of her conclusions, should be open to criticism, while the inclusion of so large a number of species seems to be unnecessary and calls for comment. That the genus *Pseudotsuga*, for instance, should have been credited with 18 species, and *Keteleeria* enriched by the addition of 4 new species, and the resuscitation of 5 others previously regarded as redundant, postulates the existence of a species-complex. In the reviewer's opinion Mlle Flous attaches too much importance to the minute distinctions which mark the variants of a wide-flung genus, and what are probably geographical forms, or at most local varieties, have been accorded the dignity of specific rank. It is regrettable that nowhere does the author clearly state her reasons for the specific segregation of these forms, nor does she indicate, unless indirectly, the affinities of the new species she has proposed. Not only are the species of other authorities reduced without examination of the type-specimens, but on occasion, as in the flagrant case of *Keteleeria Evelyniana*, the boundaries of a species have been enlarged to include forms which differ markedly from the type. The reviewer regrets that space does not admit of more than the following brief analysis of the contents of each monograph.

(1) Of the 9 species of *Keteleeria* enumerated by Mlle Flous 4 are recent, but from the descriptions of the latter it would seem that their establishment rests on rather insecure ground. *K. Chien Peii*, based on material from Kweichow, does not appear to differ materially from *K. Davidiana*, while an examination of a duplicate of one of the paratypes cited by Mlle Flous has shown that several of the characters in this particular specimen are the reverse of what she has described as typical of the species. *K. cyclolepis*, known only from the province of Kwangsi, resembles the former species in certain of its features, but unfortunately a description of the cone is lacking, although the scales and seeds are figured. Another species, *K. Dopiana*, localized in Laos, is

admittedly described from imperfect material, and its affinities remain in doubt. No type is quoted in the case of *K. Roulletii*, which may be explained by the fact that this species was placed originally in the genus *Tsuga* by Chevalier. Its home is in Indo-China, and it is distinguished from *K. Davidiana* chiefly by its leaf form, stomatal arrangement, and glabrous stem, all features of doubtful specific value. An interesting feature of the leaves is the presence of two vascular strands in place of the single bundle so characteristic of the genus. Here again, as in the case of *K. Dopiana*, the cone is described from a specimen which the author admits candidly was *très abîmé*.

In addition to these new and somewhat ambiguous species Mlle Flous has reinstated such forms as *K. Esquirolii*, *K. Evelyniana*, and *K. formosana*, held by other authorities to be merely variants of *K. Davidiana*, with which they have been merged. It is in her treatment of *K. Evelyniana* that Mlle Flous has been most arbitrary, for she has completely changed the character of this species as it was conceived by Masters by enlarging it to include all the material of *K. Davidiana* from Yunnan seen by her. That her taxonomy is at fault is made obvious when her description and figures are compared with the original of Masters, to which they bear not the slightest resemblance. Some minor discrepancies in her delineation of Léveillé's species *Esquirolii* also become apparent when the type is examined. Such inaccuracies are reprehensible in a work of this kind, and their perpetration must inevitably detract from its value as a serious contribution to our knowledge of the genus *Keteleeria*.

(2) The major part of the monograph on *Pseudotsuga*, that dealing with the American species of the genus, was published originally in 1934, and a review of it appeared in the December issue of this Journal in 1935. This former work has now been extended to embrace the Asiatic Douglas firs, and the reviewer proposes to confine his remarks to this section of the monograph. In it the Japanese, Formosan, and Chinese species are described with the same wealth of detail that characterized the American section, and here it is satisfactory to note that Mlle Flous shares the reviewer's opinion that *P. Forrestii* of western China is a distinct species and is not conspecific with the Formosan *P. Wilsoniana*. A key to all the species, American as well as Asiatic, is provided, and in it the compiler makes use of the fact, interesting in itself, that in all the Asiatic species the leaf-apex is emarginate, whereas in the American representatives of the genus it is entire.

Mlle Flous proposes two new species, *P. Gausseni* and *P. Salvadori*, the former a native of eastern China and the latter domiciled in Formosa. *P. Gausseni* is described as being akin to *P. sinensis*, from which it is separated chiefly on account of minor differences in the cone. The reviewer has compared specimens of *P. sinensis* with paratypes of *P. Gausseni* cited by Mlle Flous, and a certain amount of variation in the structure of the cones is apparent, but he is not convinced that the differences observed are constant even in the paratypes, or that they possess the significance attached to them by Mlle Flous. Furthermore, certain of the anatomical features upon which Mlle Flous also bases her claim are scarcely differential, and she is definitely wrong in denying the presence of a continuous leaf-hypoderm in *P. sinensis*, and in describing the idioblasts of *P. Gausseni* as *non étoilés*. Whether such features as these have an absolute value as deciding factors in species diagnosis, or not, is another matter, but there can be no doubt regarding the uselessness of such a phrase as 'feuilles non persistantes sur le rameau en herbier' as a key character distinguishing *P. Gausseni* from *P. sinensis* or *P. Forrestii*, since the absence of leaves from herbarium specimens of *Pseudotsuga* is more often than not the result of careless drying. As a means of identifying living

material this method is palpably absurd. The reviewer has seen no specimens of *P. Salvadori*, and therefore he does not feel competent to discuss the validity of this species, but on paper there seems to be very little to separate it from its Formosan congener *P. Wilsoniana*.

(3) The monograph on the genus *Tsuga* contains descriptions of 8 species, of which 2 are new, namely *T. Blaringhemi*, a native of Hondo, nearly related to *T. diversifolia*, and *T. tchekiangensis* from Chekiang, a species so closely akin to *T. chinensis* that there seems to be no sound reason for its separation. Mlle Flous also gives a minute description of an American hemlock which Carrière had named *Tsuga Roezlii*, and which she has seen fit to rename *crassifolia*. It is questionable whether Mlle Flous is justified on taxonomic grounds in changing the specific designation, but in any case it is very doubtful if *T. crassifolia* is distinct from *T. Hookeriana* Carrière (*T. Mertensiana* Sargent). The reasons for their separation become less convincing when the author's statements favouring it are analysed, for these create the unfortunate impression that Mlle Flous has never seen the original material of *T. Hookeriana* collected by Jeffrey, and is not wholly conversant with the characters of this species. As is well known, *T. Hookeriana* is readily distinguished from all the other species of the genus by its long cylindrical cones, and in their absence by its peculiar foliage, the leaves being rounded or keeled on the upper surface, which is here stomatiferous. It is surprising, therefore, that Mlle Flous should describe the leaf of *T. Hookeriana* as 'aplatie et sillonnée sur la face supérieure', and on the strength of this erroneous statement seek to distinguish it from *T. crassifolia*, the leaf of which she asserts is 'convexe sur la face supérieure'. Mlle Flous thus ascribes to *T. crassifolia* the special leaf-character of *T. Hookeriana*, thereby nullifying her argument, since the chief reason she adduces for the separation of these two species is the supposed difference in the form of their leaves. From her descriptions it would appear that the cones are alike.

The names used by Mlle Flous to define the various species she describes cannot in every case be justified on grounds of priority, *T. Hookeriana* being a case in point, although the reviewer agrees that to follow Sargent in the adoption of Bongard's name *Mertensiana* is likely to cause confusion. Where necessary exhaustive lists of synonyms are given, but it is evident that some of these require revision. Among these synonyms appear the names of several species which the author has reduced. These include *T. dura* and *T. Wardii*, which have been merged in *T. yunnanensis* and *T. calcarea* respectively, but in this case such an action is indefensible, for apparently it was determined upon without any examination of the type material.

It is a matter for regret that so much of the subject-matter in these monographs should be deserving of adverse criticism, for the idea underlying them is excellent, if only greater care had been exercised in their preparation; even so they contain a considerable amount of useful information if one is prepared to sift the wheat from the chaff.

The Root System of Birch. By Erkki Laitakari. *Acta Forestalia Fennica*, No. 41, 1935.

Review by James Fraser

THE original paper is printed in Finnish. A very full summary is given in English and the tabular statements in the Finnish text have English translations, so that those statements are intelligible to English readers. There are 44 pages of drawings and photographs which are all provided with English translations.

The paper deals with the general external form and structure and extent of the root system of birch. The investigations follow the same lines as the earlier investigations made by Laitakari on pine,[1] and the methods used and the presentation of the results are similar to those of the earlier paper. The list of references used in the work extends over three pages; in the English summary a short account is given of the descriptions of the birch root system that have appeared in various text-books, and short summary statements are given of works dealing with root systems published since 1927. Frequent references are made to the work done by other Finnish workers in recent years on questions affecting root systems.

The observations which are used were made in 28 sample plots distributed over four parishes in the southern half of Finland. Investigations of birch roots which were made during the course of the work on pine have been used in the present work. During the work on those plots a certain amount of work has been done on spruce roots and the observations have been used for comparison with the pine and birch roots, but on account of the circumstances the statements dealing with spruce have not been given undue weight. The birch-trees investigated vary in size from seedlings to trees measuring 22 cm. in diameter at breast height and 16–18 metres in height: ages of the trees are between 1 and 150 years: sample trees have been taken from the Cajander types CT, VT, MT, OMT, spruce moss, and pine moors. Laitakari states that it may be desirable to investigate more fully the systems to be found in swamp types.

The root system of the birch in the seedling stage shows a tap root and a horizontal system. With increasing age the tap-root system disappears; the original tap root may take a horizontal direction of growth and strong vertical or steeply sloping and deep-going roots may develop from the base of the stump. Certain of the vertical or steeply inclined roots may grow out in a horizontal direction after they have penetrated to a depth that is not fixed. The deep-going roots that occur close to the base of the stump are described as 'inner deep roots'. Vertical roots arising by a growing downward of the tip of a horizontal root or formed from a branch of a horizontal root are referred to as scattered deep roots. Those scattered vertical roots are found in birch.

The form of the birch root system shows the effect of the growth conditions early in its life. Varying soil conditions are naturally likely to produce varying forms of roots. In addition Laitakari shows that wind and ground frosts and the presence or absence of former generations of roots are important modifying conditions in the form of root. Horizontal roots and scattered vertical roots of birch may be found growing in the channels and even inside the bark cover of the old dead roots. Mycorrhiza is generally present in the finest branches of the root system and is generally most plentiful in productive spruce moor types.

Those horizontal roots which have their origin close to the base of the stump are very frequently flattened in a vertical plane. This flattening is regarded as an adaptation that strengthens the tree against wind-throw, and figures and observations are provided to support this view. It is stated that the flattening is more common and that the degree of flattening is more intense in the birch than in the pine. Laitakari states, however, that the three strongest roots are not found in the same 'quarter' on the birch-root system as in the pine roots.

Figures dealing with the length of the horizontal root system lead to the conclusion that the horizontal root system reaches its greatest total length in poor sandy soils. Sandy soils which differ in the nature of the forest type give a striking difference of the effect of soil fertility on the total length of the horizontal root system. If the total

[1] Reviewed in this Journal, iii. 1, p. 66.

length of the horizontal root system of birch is compared with that of the pine it is seen that the birch has the greater length, and also compared with spruce. Figures are also given to show that the greatest length in single horizontal roots of birch is attained on poor sandy soil and that on spruce moor the greatest length attained by a single root is always relatively small. Comparison of the range of variation in total length of the horizontal root system in pine and birch leads to the conclusion that the birch possesses a horizontal root system that is more responsive to the nature of the soil so far as this can be judged from the total length of the horizontal root systems.

The area of the horizontal root system is measured by the number of units of area within which those roots are found. Figures show that in poor sandy soils of VT the areas occupied are greatest. In spruce moor the area occupied is lowest. A very striking variation according to type is shown on sandy soils. The comparison of area occupied by birch roots as compared with the area occupied by pine roots shows that in poor qualities of soil the birch occupies a much greater area than does the pine, but that in richer qualities of soil the difference decreases. On the richest types the pine roots occupy a larger area than spruce. Figures available for making a comparison with spruce indicate that the area occupied by the spruce horizontal roots is greater than that occupied by the birch.

In making the comparisons of the total length of the root systems, and of the areas occupied by the root systems of individual birches in various circumstances and of birches with pine and spruce, a 'converted' figure is used. The object of the 'converted figure' is to make the comparison between trees of 10 cm. diameter at breast height.

A further set of measurements indicates the length of horizontal root found in a unit of soil. The figure obtained by this reckoning is taken as a measure of the density of the horizontal root system. Those figures show that the greatest total length of root system is found in the richest types and that the shortest lengths are found in the poorest types. When the comparison is made with pine it is seen that in all the types investigated the greater lengths were shown by birch. The comparison with spruce shows that the density of birch is higher than the density of spruce.

The diagrams and photographs illustrating those comparisons are very good, and for most men they will convey impressions that are more lasting than the impressions made by the statements of conclusions drawn from measurements.

The most valuable part of the investigation is probably the conclusion drawn with regard to the varying depths at which the horizontal roots of birch, pine, and spruce are found. Birch horizontal roots work at the lowest level; spruce roots work at the levels nearest the surface, and pine roots occupy an intermediate position. Those differences are seen most clearly in sands and on moraines rich in stones. If comparisons are made between the depths of birch horizontal root systems in different soils, it is seen that the greatest average depth is in moraine, the shallower average depths are found in clays and waterlogged moor and shore gravel. Laitakari's views on average depths attained by the horizontal root systems are stated with caution, and in this short summary it is difficult to give a short statement that may not be unjust to the original statement.

The central vertical root system of birch is best developed on moraine and sandy soils. A real tap root on large-sized trees is rare, but strong slanting roots may be developed in the central root system. Scattered vertical roots are most common in sandy soils and clays, but they are found also in moraines. Those scattered vertical roots are thin: they may penetrate to depths of even 270 cm. and may develop tufts of fine roots along their lengths. In sandy soils they appear to follow channels left by

decaying roots: in clay soils they appear to follow cracks in the clay. Those deep roots do not appear in soil that is waterlogged.

Statements and figures dealing with the volume of the root system demonstrate that the volume of the vertical roots as compared with the total volume of the roots is very low. The total root volume of horizontal and vertical roots combined in small trees may exceed the volume of the tree stem, and in the trees described in the tabular statements no tree appears in which the volume of the root system is less than 30 per cent. of the stem volume.

The descriptions of the external forms of the root systems of birch as given by Laitakari differs in many points from the descriptions which have become traditional.

Several paragraphs are devoted to the length of life of root systems of felled birch trees, the occurrence of clusters of buds at the base of the tree below ground-level, the 'marching' of root systems of separate trees, and the causes tending to kill off parts of the root system.

Silvicultural conclusions which Laitakari draws from the observations are of first-class importance. It is stated that on a forest area which is capable of growing birch, pine, and spruce the most economic use is made of the soil and the biggest volume for the whole area is produced by growing those species in mixed woods. The greatest advantage is obtained in mixtures by individual trees. His conclusions are based on the distribution of the root systems of the trees. He does not claim that there is no competition among the roots of the species in the mixture, but he does claim that the competition between the horizontal roots of neighbouring trees of different species is less than the competition between neighbouring trees of the one species. His conclusions with regard to a birch-pine mixture are fully supported by the conclusions drawn earlier by Lappisippala from measurements of volumes. Volume figures to support the claims for a birch-spruce mixture are not given. Burse's investigations 1931 support the view with regard to a pine-spruce mixture. Laitakari's view is that the most easily managed mixture is the pine-birch mixture. In a spruce-birch mixture the spruce apparently suffers sometimes by the whipping of birch, and on that account the woods may require more careful attention. The mixture may tend to produce very fine, clean, heavy birch, but may produce deeply branched spruce. Birch-pine or birch-spruce mixtures have marked advantages over spruce-pine mixture on account of the greater ease with which natural regeneration is obtained in the woods where birch forms a part of the crop. It is claimed that birch trees left as standards in a wood under regeneration are not more liable to wind-throw than pines. The well-established thinning rule of breaking groups receives fresh interest. Freely interpreted his view may be read: that it is more possible without economic loss to retain a canopy in a mixed wood than in a pure wood. Thinnings should on that account be directed towards obtaining a mixture of species by individual trees. A warning is given against the removal of birch in mixed woods even in areas where the sale-value of the birch is low.

Views expressed by Aaltonen at an earlier date with regard to the growing-space required by trees of the one species on soils of different fertility are briefly referred to. Laitakari also directs attention to the need for considering more than the part of the tree that is above ground in the carrying out of thinnings. His work disproves the belief that the area over which roots extend coincides with the space covered by the vertical projectors of the crown. On old abandoned farm land it has been found easier to regenerate a spruce wood when there is a birch screen than when the area is bare. The explanation given is that the soil texture is more open under the birch screen.

On spruce moors he claims a similar advantage for spruce grown under a birch screen and explains the advantage by the drying effect exercised by the transpiration of birch.

Studies on the Development of Conifers in Raw-Humus. III. The Growth of Scots Pine (*Pinus silvestris*, *L.*) seedlings in pot cultures of different soils under varied radiation intensities. (In English with a Swedish Summary.) By P. R. Gast. *Meddelanden från Statens Skogsförsöksanstalt*, Häfte 29, No. 7–9.

Review by G. K. Fraser

IT is difficult to do justice to this admirable piece of research in a short review. A section of the same series of experiments has been reviewed in this Journal by Aldrich-Blake (vol. ix, no. 1, p. 75). (Some of Aldrich-Blake's own data are used here for illustration.)

The experiments recorded in the paper were devised to study the effects of simultaneously varied mineral nutrition and radiation (from the sun) on the growth of Scots and White pines. As soils there were used sand, and sand mixed with different grades of humus, and in addition sand flooded intermittently with nutrient solutions ('nutrient-sand cultures'). Radiation was altered by graded lath covers, by wire-cloth screens, and by water screens, i.e. shallow and wide glass boxes filled with water. The methods used are described in detail or are referred to appropriate authorities. The experiments were carried out during the years 1930–4, at first in Sweden, subsequently at various stations in the U.S.A.

The contents and quality of the work can be readily inferred from a review of some of the chief conclusions reached, but the most conclusive and suggestive section of the work may be felt with justice to be, not that to which the title refers, but the more precise and fundamental studies in the sand-nutrient cultures.

In these, the effects produced on the growth of pine seedlings by varying radiation and nitrogen supply can be mathematically stated with precision, provided due consideration is given to factors such as variation in seed weight which may obscure the measurements obtained. A statistical method is developed for obviating this source of confusion, and then it is shown that there is a definite relationship between the weight of seed used and the weight of seedlings obtained from these under given conditions. If the 'reserve dry weight' of the seed (i.e. the weight of seed less that of the seed coat) is used in place of the weight *in toto*, then this relationship is one of direct proportion. Thus, when grown in nutrient-sand cultures, at known concentrations of radiation and nitrogen supply, the weights of seedlings obtained from seeds of known weight can be accurately predicted, and definite relationships are found to exist between the nitrogen supply, the nitrogen uptake, and the dry weights of seedlings. Some of these relationships are direct and some are logarithmic and more complex. In another paper by a co-worker it will be shown that phosphate is similar to nitrogen in this respect; but, on the other hand, potash does not give results which are capable of any simple mathematical formulation.

In temperate humid regions north of 40° latitude, when radiation falls below 20 per cent. of its ordinary intensity, it becomes the major limiting factor to seedling growth: above 30 per cent., nutrient supply is more important. Within limits, growth (as measured by dry weight) is logarithmically related to the cumulative radiation received. The responses made by different pines (Scots, Corsican, White) to equivalent increases in nitrogen supply are found to differ, Scots pine showing greatest response and White pine the smallest.

The application of these basic conclusions to humus-sand cultures has presented some difficulty. Curves are given to show the relative yields from 'good raw humus, burnt raw humus, bad raw humus and sand' under varying intensities of radiation. From analysis of the seedlings it is held that, as distinct from potash and phosphate, nitrogen deficiency is a limiting factor. It thus becomes necessary to determine the available nitrogen in the soils. In the opinion of the reviewer, it cannot be held that this problem has been satisfactorily solved here, or indeed that it has been shown to be capable of solution. The solution given is as follows: 'As a measure of the nitrogen availability it is, therefore, necessary to use the quantities of nitrogen in the seedlings themselves. The external supplies of available nitrogen are then assumed to be directly proportional to the nitrogen content in milligrams in the seedlings.' At least it is certain that the general applicability of such an assumption requires very careful proof, however useful it may be as an approximation. But this problem involves many considerations, some of which are discussed here.

The application of the data to field conditions is reviewed. At radiation intensities below the limit indicated above, pine does not develop a vigorous root system and well-balanced shoot/root ratio, even on good sites. Therefore seedlings germinating under canopy producing such a degree of shade are unlikely to result in a good regeneration crop. Their poor root systems, developed mostly in the H and F layers, will, following the removal of the parent crop, succumb to drought. Such seedlings have a shoot/root ratio of 3·0 to 3·5 and over. The practical application is obvious—seed fellings for Scots pine should be heavy enough to admit to the forest floor at least 20–30 per cent. of the normal sunrays, otherwise properly balanced seedlings are not obtained.

Only some of the conclusions reached have been referred to above. But it is not only in the results obtained that the value of this paper lies. Most workers on similar lines—the scarcely touched field of the nutritional physiology of conifer seedlings—will find many hints as to methods and apparatus, while the paper is a good example of the use and value of statistical and graphical analyses of growth phenomena.

'Studier över Tallskottvecklaren, *Evetria buoliana*, Schiff. Del. I.' V. von Butovitsch. *Meddelanden från Statens Skogsförsöksanstalt*, Häfte 29, Nr 5. 1936. (In Swedish with a German Summary.)

Review by J. M. B. Brown

THIS paper presents the results of a study of the Pine-shoot Tortrix moth in southern and central Sweden. The German summary, studied in conjunction with the excellent illustrations (all 30 of them original and provided with German explanations), and a series of illuminating tables which are scattered through the Swedish text, indicates that the paper itself is a very useful addition to the literature dealing with this troublesome pest.

The author discusses first the distribution of the insect as a pest. After recording that its distribution embraces the whole of Europe, he places the centre of its breeding-ground in the land surrounding the Baltic Sea—Denmark, northern Germany, southern Sweden, and the newer Baltic countries. For readers familiar with the recent publications of De Gryse (1932), Friend and West (1933), or Brooks (1936) the account of the biology of the insect contains little that is new. Further evidence is given about some of the less-known facts, such as the preliminary attack on the needle-bases by

the newly hatched larva, and there is an interesting discussion of the factors which release a second annual brood in some Mediterranean countries.

The various forms of injury which follow *E. buoliana* attack on the main shoot are listed and adequately figured. In considering direct measures of control the author discusses the American attempts to destroy the young caterpillars with chemicals before their invasion of the buds, which protect them for the remainder of their larval life. Good experimental results have been obtained with several sprays, but none has yet proved itself effective and yet cheap enough for use in practice. The prospects of successful control by the pruning of infested shoots are also considered in this section.

The section devoted to ecology treats of some matters which are of considerable importance to the forester. The distribution of the attack over the various parts of the crown and as between the centre and side buds of infected whorls are dealt with statistically. Whereas the attack is more intense in the higher branches and particularly on the leading shoot, the distribution of the attack among the several buds of the whorl appears to be determined by the laws of chance, with the net result that half of the whorls lose their central bud, when invaded by a caterpillar. The author considers it exceptional for several caterpillars to settle in the same whorl, but this was far from being the case in many plantations in East Anglia. The influence of various ecological factors on the multiplication of the insect and on the severity of the injury caused by it are considered in detail, and this section of the paper (pp. 543–9 in the German text) merits study by all practical foresters who are concerned with *E. buoliana* as a pest. Direct control measures having hitherto failed, it is only by modifying these factors that we can hope to give protection to pine plantations in infested localities. The reader is referred particularly to the discussion of soil conditions and their direct and indirect influence, of the scarcity of Tortex on mature pines, and of the effect of the light-factor and the spacing of the trees in the plantation. If the author's conclusion is justified, that sunlight powerfully fosters the insect and that fast-growing, even, and densely stocked plantations are much less severely handled than slow-growing, uneven, and open plantations, a means of controlling the pest through this factor lies within the reach of the forester. It is a matter of observation, at least, that in even, vigorous plantations the conditions for recovery from attack are more favourable. In this connexion the indirect influence of poor soil merits attention. This is more or less the substance of Dr. Butovitsch's conclusions in regard to the practical control of *Evetria*, which he gives on page 555, but he considers that the usual Swedish spacing of the plants (100 or 110 cm. apart each way) is too wide and recommends the reduction of this figure to 90 or 80 cm. This would involve 5,000–6,000 plants in an acre. It would not be easy to convince the English forester that his extra cost of planting would be repaid by comparative immunity from shoot-moth injury.

Erkennen, Nachweis und Kultur der holzverfarbenden und holzersetzenden Pilze. By W. Bavendamm. Reprint from the *Handbuch der biologischen Arbeitsmethoden*, vol. xii, part 2, pp. 927–1134. 1936. Berlin.

Review by W. P. K. Findlay

ALTHOUGH a great deal of research has been carried out on the causes of decay and deterioration in timber and numerous descriptions exist of the most important fungi which attack wood, yet there have been very few attempts to bring this knowledge together in the form of text-books. Therefore we welcome this volume published recently as a reprint from the *Handbuch der Biologischen Arbeitsmethoden.*

The author has surveyed the literature very thoroughly, giving 14 closely printed pages of references, and, unlike some continental workers, has not overlooked the large amount of work which has been published in America and also the more recent work carried out in this country. This volume is not merely a conscientious compilation from the literature, because the author makes critical comments on many of the papers noticed and describes the nature of their contents. The opening chapters contain keys to the various types of rot in different timbers which would be very useful were they more complete. The various tests which have been used for determining the soundness of timber and the mechanical and physical properties of decayed wood are then described. Methods for the staining and examination of diseased wood and for the culture of wood-destroying fungi are referred to in detail. Existing knowledge on the mechanism by which wood substance can be decomposed and on the physiological activities of lignicolous fungi is summarized. The conditions which influence the fructification of Basidiomycetes in culture are also described. The literature on blue stain and on the organisms responsible for sap-stain is referred to only briefly.

This volume should be useful to any one working on any problems concerning the decay of timber and should be of particular assistance to those approaching the subject for the first time, as it would enable them quickly to become familiar with existing knowledge on the subject.

Het Geslacht Populus *in Verband met zijn Beteekenis voor de Houtteelt* (*The Genus* Populus *and its Significance in Silviculture*). By G. Houtzagers. Pp. 266. H. Veenman en Zonen, Wageningen. 1937. Price 10*s.* 8*d.*

Review by P. G. Beak

FOR some years there has been an increasingly urgent need for a comprehensive survey of the poplars, many of which are economically important or likely to become so. Elwes and Henry's *Trees of Great Britain and Ireland* and Rehder's *Manual of Cultivated Trees and Shrubs*, the two most reliable sources of information on the genus, are both almost inaccessible to the general reader and seriously out of date in some respects. The present very thorough work should therefore prove a welcome addition to the existing literature.

Although the general treatment is botanical, the opening chapter contains very full statistics on distribution and utilization. In Holland, poplars are grown mainly as a secondary crop along roads, canals, and the sides of fields. Through the co-operation of local authorities all over the country, it has been possible to make up a complete census of the individuals of each species growing in the several provinces; the results are recorded in tables, and a map illustrates the distribution of the important kinds. From the totals for the whole country it seems that × *P. serotina* and × *P. marilandica* are by far the most commonly cultivated forms. Average figures are given for the rotation (about 25 years), total annual increment (about 80,000 cu. metres), girths, timber-length (12–14 m.), taper, and volume per tree (about 1 cu. m.). In first-class districts the figures are much better, and it is pointed out that improvements in culture and the use of selected strains may raise the annual increment still further. The sizes of timber in demand for various purposes may interest British growers; the required girths are as follows: exportation, 1·8 m. and more; match-wood, 1–1·4 m.; wooden shoes, 1·35–1·55 m.; plywood, 1·2–1·5 m. (in lengths of 2·6 m.); sawn timber, 0·3 m. (minimum); pulp-wood, 0·1–0·25 m. (in lengths of 1 m.).

The incredible confusion in botanical and trade names of poplars is a serious source

of trouble to growers, who may receive all kinds of wrongly-named material for which extravagant claims are often made. Dr. Houtzagers sees in the publication of a logical classification, correlated with the local names in use, the first step towards his ideal of national institutions to control the propagation and distribution of guaranteed stock. His own nomenclature is mainly that of Elwes and Henry, and there are no striking innovations, except for two new hybrids, one of which (× *P. gelrica*) may become a valuable timber-tree.

Chapter 2 deals with classification and gives brief descriptions of all species likely to be met with in Europe. The succeeding chapters are devoted to the Black poplars and their hybrids; lists of local names, detailed descriptions, and discussions on nomenclature, origin, and distribution are provided for each form. Next follow tables of phenological data together with remarks upon their value as characters, and an excellent series of leaf-photographs.

Though sometimes showing traces of its foreign origin, the English summary is clear and does justice to the main points of the Dutch text. A special feature is the translation in Chapter 12 of a key to the species and a tabular view of the characters of the Black poplars and hybrids. The legends of the numerous and admirable photographs throughout the book have also been translated into English.

An exhaustive bibliography and an index to names complete the work. Other specialists are collaborating with Dr. Houtzagers in the preparation of a supplement dealing with cultivation, diseases, utilization, &c.—matters which could not conveniently be discussed in detail within the limits of the present volume.

The Employment of Species, Types, and Individuals in Forestry. By C. Syrach Larsen. Reprint from the *Royal Veterinary and Agricultural College Year Book.* C. A. Reitzel, Copenhagen. 1937.

Review by the Editor

MANY British foresters know Mr. Larsen personally through his visits to this country, and they will turn with interest to this book. It deals with types, hybrids, and breeding of forest trees, and while somewhat discursive and tentative, it contains much interesting matter, both historical and original, and some attractive ideas. Denmark has been more receptive to new tree species than any other European country except our own, and it is thus appropriate that she should advocate the next logical step.

In the first section of the book Larsen discusses the simple selection of a particular type of a species, and gives as examples the so-called Dunkeld race of European larch and what he calls the 'Scone Douglas fir'. The views of Schötte and Oppermann on the Dunkeld larch are well known, and Larsen has little to add. The original 'mother trees' at Dunkeld were undoubtedly of good type, and they probably had a large progeny particularly in Perthshire, but there is little or no precise knowledge of what, if any, existing larch plantations in Scotland are descended from the Dunkeld 'mother trees', or other early introductions. Likewise Larsen considers that the two old Douglas firs at Lynedoch in Perthshire, which are reputed to have been raised from seed sent home by David Douglas, were the source from which the seed was obtained for most of the older plantations, particularly on the Scone Estate, including the famous Taymont Plantation, the trees of which are considered by Larsen to have been a good type. The reviewer considers that the question of types of Douglas fir in Scotland should be gone into again carefully. The evidence is that the type of tree obtained

from seed imported during the past 20 to 30 years, while variable, has generally been unsatisfactory, and this has led to the present unpopularity of the species. Although the factor of age should not be overlooked, the older trees generally appear to be of better form and are more windfirm, and it would be worth while to endeavour to raise crops from the best of the old trees, even although the germination percentage was low because of *Megastigmus* damage.

Larsen then discusses the distribution of male and female flowers in different species, and the relative time of flowering of each sex, in relation to self- and cross-pollination. This section gives a useful summary of available knowledge on this subject, but much remains to be determined before we have full accurate information for our principal tree species.

The next section deals with tree hybrids, and those occurring in nature, e.g. the Scots pine and Mountain pine hybrid, those occurring in cultivation, e.g. the Hybrid larch, and those artificially produced, e.g. the Burbank walnuts, are considered in turn. Here also much interesting information is brought together.

Under breeding, while artificial crossings are not excluded, the most interesting suggestion is that seed-producing plantations should be formed in places where there will be no pollination from outside sources (if this is possible), and that methods of vegetative reproduction, grafting and cuttings, be employed to build up such plantations from the best existing material. The whole question deserves careful consideration, and one important step could be taken at once, that is, to institute some control over tree-seed collection in this country on the lines already employed in Germany and elsewhere.

The book contains many and good illustrations, including some in colour.

British foresters will wish to congratulate Mr. Larsen on this interesting and important book, and to thank him for publishing it in English.

Studier över Tallens Fysiologiska Variabilitet och dess Samband med Klimatet Ett Bidrag till Kännedomen om Tallens Ekotyper (Studies of the Physiological Variabilities of Scots Pine and their Connexions with Climate. Contribution to the knowledge regarding 'Ökotypes' of *Pinus silvestris*). By Olof Langlet. 35 Tables; 37 illustrations, maps and diagrams. *Meddelanden från Statens Skogsförsöksanstalt*, Häfte 29, Nr. 4. Stockholm, 1936. (In Swedish with a German Summary.)

Review by J. Alan B. Macdonald

IN this paper Langlet records further progress in his researches and brings up to date the account given in 1934 (reviewed in this Journal, vol. viii, no. 1).

The aim of the work was twofold: (*a*) the examination of Scots pine plants of different proveniences with a view to establishing possible definite differences related to cold-resistance; (*b*) the study of the relationship between the established differences of the examined proveniences and the climate at the place of origin.

The paper begins with a summary of the development of the provenience question, especially in Sweden. This is followed by a survey of the physiological basis of cold-resistance, and more particularly discusses the physiological facts regarding cold-resistance of Scots pine plants. Apparently cold-resistance can be considered basically as an expression of the physiological general condition. Langlet next deals with variations during the year of certain materials occurring in the plant cells; also the connexion

between cold-resistance and the concentrations of these materials. As a rule it holds that as the water content diminishes in autumn the dry-matter content increases. Starch and acidity, as well as chlorophyll under certain circumstances, decrease, while sugar, fats, reserve cellulose, tannin, and catalase, among others, increase. These changes (which go on concurrently and appear to be more or less dependent on one another) mark the change into the condition of winter rest, that is to say, hardening. The degree of cold-resistance which one and the same plant exhibits at different seasons of the year corresponds, therefore, with the different content of dry matter, sugar, &c. In the same way different races of one species can be graded according to frost hardiness through their having different contents of the above-mentioned materials. Besides dealing with variations of dry weight, sugar, and fats, mention is also made of such materials as hemicellulose, nitrogen-containing materials, and enzymes. Osmotic values, strengths, acidity, and winter colouring are also discussed.

Pine plants of northern origin show a proportionately high content of dry matter, sugar, &c., in autumn and winter.

(Extract from Table 9, p. 269.)

Dry-matter content of one year Scots Pine Seedlings.

Origin of seedlings.	*Dry-matter content as a percentage of fresh weight.*	*As a relative value.*
Norway . .	31·1–39·6	78·5–100·0
Finland . .	35·6–39·4	90–99·5
Russia . .	30·3–36·9	75·5–93·0
Latvia . .	32·2	81·5
Germany . .	29·9–32·1	75·5–81·0
Scotland . .	30·1	76
Poland . .	29·7	75
France . .	29·3	74
North Italy .	29·1	73·5
North Spain .	27·0	68

At the same time northern plants show a somewhat higher content of total nitrogen, and, on the other hand, a more limited amount of plant fibre and materials extractable with weaker acids and lyes. Pine plants of northern origin exhibit more or less intensive winter colouring, which is bound up, at least in the needles of older plants, with reduced chlorophyll content, corresponding to the intensity of the yellow winter colour.

From a planting experiment carried out with pine plants of one provenience in the Külbäcksliden, Tonnersjöheden, and Gällivare Experiment Districts, dry-matter contents were determined at the experiment station. Close correlation was established between on one side the dry-matter content at the research station, and on the other the over-wintering ability of the plants, their condition, rate of growth, needle length, and winter colour on the three areas. Needles of pine of northern proveniences develop earlier in the spring than those of southern proveniences. The earliness of the needle development at Tonnersjöheden was shown to stand in close relation to the dry weight ascertained for the various proveniences at the experiment station. The dry-matter content is an estimation which is easy to ascertain, and which is characteristic for plants reared under similar conditions. It expresses the physiological variability of the plant as well as how these plants (in the mass) vary as regards sugar-content, catalase, &c.,

or in different intensities of winter colour. It expresses also how they vary in different overwintering abilities, in qualities of the plants, in rate of growth, in needle-length, and in periodicity (i.e. time of flushing and termination of growth—growth period). Cone size, seed weight, root system, specific weight of timber, and drought resistance are discussed. There is also a report on a planting experiment carried out with different races in 1931, which gives the number of living plants, their condition, height, and needle form, &c., when assessed in 1934.

In dealing with the connexion between content of dry matter and climate at the home of the race under examination, meteorological charts were made showing the number of days in the year with normal temperature of +6° C. and over. Other charts showed the mean temperature of the warmest months and the difference between the mean temperature of the warmest months and coldest months. The rainfall is also represented graphically. Statistical examination showed that the dry-matter content of pine plants of definite origin can be considered as a function of (*a*) the geographical latitude of the habitat—there is a most striking series of maps facing page 339—and (*b*) of the growing season when the latter is expressed as the number of days per annum when normal temperature was +6° C. or over. In Sweden (excluding the west coast) this number of days is essentially an expression of the latitude of the station and its altitude.

The distinction between pine proveniences with respect to dry-matter content is in some cases established as hereditary. The opinion of Schott, Engler, and others that the physiological variability of pine is continuous was confirmed by Langlet's research. From a comparison of different 'Ökotypes', or ecological units, of one kind of plant, it appears that the conception 'Ökotype' can be fully applicable to pine proveniences which differ from one another from the physiological point of view. A continual variability is then to be expected if the outer conditions on which the variability depends vary continually. The continuity must, therefore, be characteristic of the so-called geographic variability.

The three dimensional graphs shown are based on the results of the afore-mentioned experiments at Külbäcksliden, &c., and refer to plants reared at the experimental station, which were planted out as 2-year plants and since then have been growing 3 years in one or other of the experimental areas. It is claimed that this kind of diagram provides a good representation of the results of the transfer of pine seeds from one place to another and makes it possible for results of different combinations of place and provenience to be directly compared.

One is impressed by the thorough and comprehensive nature of the work carried out. Although much of the detail in the report will interest only the plant physiologist and the biochemist, the forester will appreciate the importance of Langlet's researches.

NOTICES

La Moria dell' olmo (*Graphium ulmi*). By Gabriele Goidánich. Ramo Editoriale degli Agricoltori, Rome. Price 8 *lire*.

DR. GOIDÁNICH, the author of this book on Dutch Elm Disease, has made an intensive study of the subject in Italy, first at Bologna, and latterly under Professor L. Petri at the Royal Station of Plant Pathology at Rome. Because of the importance of elms in Italy, the Italian Government gave financial support, which enabled a comprehensive survey to be carried out over the whole country.

The elm is important in Italy for an interesting reason. In many provinces of

northern Italy elms are planted in rows, and wires are fixed to them to support vines. The live supports are claimed to be better than posts, and millions of elms are used in this way. *Graphium* disease has caused a heavy mortality amongst these elms, hence the importance of the subject. The disease is distributed throughout Italy except in the extreme north and the extreme south.

The book, which is well illustrated, is divided into four sections: the host, the different elm species; the parasite; the causes of the disease; and control measures. The author recommends the Siberian Elm (*U. pumilia*) as a resistant species and states that 'this new introduction has justified all the hopes placed on it'. In addition to its usefulness as a support for vines, it provides food for cattle.

So far as this country is concerned, *U. pumilia* grows slowly and is subject to damage by *Nectria*. Further, no stocks are available. The Dutch resistant seedling No. 24 is more promising, but here again it will be several years before considerable supplies are available.

The Plant Diseases of Great Britain. A Bibliography. Compiled and annotated by G. C. Ainsworth. Chapman & Hall, London. 1937. Price 15*s*.

DR. AINSWORTH is to be congratulated on the compilation of this bibliography of plant diseases, including those of trees, in Great Britain. The arrangement is under host, and, in addition to titles of papers, reference is made to abstracts in the *Review of Applied Mycology*, and in many cases a short description is given of the scope of the paper. Most of the papers cited are British, few references to foreign literature being given. For example, under *Rhabdocline pseudotsugae* reference is made to the Dutch paper by Van Vloten, but no mention is made of the numerous papers in German journals in recent years. Nevertheless the book will be very useful not only to applied mycologists but to the scientific agriculturist, horticulturist, and forester.

Soil Erosion and its Control. By Quincy Claude Ayres. McGraw-Hill Publishing Co., Ltd. London, 1936. Price 21*s*.

THE subject of soil erosion has been receiving increasing attention in recent years, particularly in America. It is claimed that this American book is the first general text-book on the subject. America appears to be tackling her vast erosion problems seriously, and this book should aid, not only in the training of those who will have to deal with erosion control, but also in the general education of public opinion. The subject is also of paramount importance in many parts of the Empire, and as forest officers are often charged with the execution of control measures, the book will also be welcomed in forest schools in this country.

The subjects dealt with are: factors affecting rate of erosion; methods of control; rainfall and run-off; terrace design, construction, and maintenance; control of gullies; various types of dams; special uses of vegetation; and soil conservation and land use.

Emphasis is placed on engineering methods of control, but, as stated by the author, this is because this aspect is better developed. There are numerous illustrations, but the reproduction of some of the photographs is only mediocre.

British Trees and Shrubs. By H. Gilbert-Carter. Clarendon Press, Oxford, 1936. Price 12*s*. 6*d*.

THE author states that the object he has in view in issuing this book is 'to teach students to distinguish our native woody plants and many cultivated ones by means of curt diagnoses somewhat like those that are the strength and beauty of

Hooker's *Student's Flora*'. The object is admirable, but is difficult of execution, for two reasons. First, there is the question of selecting what to include. Comprehensiveness would make the book very large, but as it is, the user will often be in doubt whether the specimen he is attempting to identify is included in the book. Secondly, it is doubtful whether the descriptions of species given are sufficient to enable identifications to be made without illustrations. Engler's System of Classification is followed, and descriptions are given of the Subdivisions, Classes, Families, Tribes, Genera, and selected species. One of the most attractive features of the book are the footnotes giving the derivations of plant-names. The book concludes with a bibliography and a glossary of terms used. It is a useful addition to our literature.

International Year Book of Forestry Statistics, 1933–35. Volume I, Europe and U.S.S.R. International Institute of Agriculture, Rome, 1936.

THIS useful volume brings together a large amount of statistical information for European countries. It is divided into forest statistics, and statistics of trade in wood and certain wood products. The data are given both in summary form and by country. The first division includes information on the composition of forests, nature of ownership and treatment, distribution by species and age, growing stock, annual increment, &c., as far as information is available, while, under the second division, information is given of exports and imports, &c., for 1930–4. Such a volume shows how useful it would be if greater uniformity in units and classification of produce could be secured.

A Handbook of Home-grown Timbers. Forest Products Research Laboratory. H.M. Stationery Office, 1936. Price 1*s*. 6*d*.

THIS volume gives a general description of each timber which is followed by notes on its seasoning, mechanical properties, natural durability, preservative treatment, wood-working qualities, and its liability to insect attack, with a summary of its uses. The information is presented concisely and lucidly, and the format is the same as the attractively produced *The Principal Rots of English Oak*. It is a book which should be in the hands of every forester.

Dry Rot Investigatons in an Experimental House. Forest Products Research Records, No. 14. H.M. Stationery Office, 1937. Price 6*d*.

SIX years ago an experimental house was erected at Princes Risborough for the study of the relation between method of construction and dry rot. There were three general methods of construction, each being further subdivided: solid floor, hollow floor without ventilation, and hollow floor with adequate ventilation. Artificial infections by dry-rot fungus were made. This Report by Mr. W. P. K. Findlay gives the results which have been obtained. It has been shown conclusively that, if a floor is properly constructed and ventilated, dry-rot fungus will not develop, hence method of construction is more important than absence of infection. One method of construction sometimes followed in reconstructing old cottages, namely, nailing floorboards directly to battens embedded in concrete, has been found very unsatisfactory, and this confirms general experience. This report should be in the hands of all who have to deal with building construction.

The National Home-grown Timber Council. First Annual Report, 1936. Price 1*s*.

THIS body was formed in 1935 'To provide a permanent link between growers, buyers, distributors, and users of home-grown timber, and in connexion therewith to prepare and distribute trade information and statistics, to study economics, to undertake research, and to promote propaganda in relation to home-grown timber, and to conduct negotiations on behalf of the Home-grown Timber Industry with the Forestry Commission, Government Departments, public and other bodies, corporations, companies, or persons on all matters affecting the interests of the industry.'

The first year has been spent principally in surveying the general position, and the report brings together useful information, most of which had been prepared by various interested bodies. Emphasis is placed on two points: first, the urgent need for a census of existing plantations and for legislation for compulsory returns of fellings; and secondly, the development of the production of mining timber so that necessary thinnings may be carried out. When the Council was appointed the industry was in a very depressed state. The situation has changed completely during the past few months, and, particularly as regards mining timber, prices are so attractive that there is no excuse for neglect of thinning. Nevertheless, there is still plenty of scope for the better organization and development of the home-grown timber industry, both for peace and as a defence measure.

Report from the Select Committee of the House of Lords on Agriculture (*Damage by Rabbits*). H.M. Stationery Office, 1937. Price 1*d*.

THIS is an uninspiring and largely negative document which is not likely to contribute to the admittedly difficult problem of reducing the excessive rabbit population in this country. It is worthy of note, however, that the Committee resisted the propagandist efforts to secure the recommendation that gin traps be abolished in favour of gassing. The latter is of limited utility, and if rabbits are to be reduced every appropriate method will have to be used, although unnecessary cruelty should be avoided.

The Imperial Forestry Institute, University of Oxford. Twelfth Annual Report, 1935–6. Oxford, 1937.

IN this Report the results of the deliberations of a special committee set up to consider future policy are set forth. In summary these are as follows: 'The aim is to develop the Institute as a centre for the study of world forestry in relation to Empire forest problems, and as a forum for the interchange of professional knowledge amongst foresters from all parts of the Empire, rather than as a place of instruction *ex cathedra*.'

A further development is the formation of a Documentation Section and the issue of a *Current Monthly Record*. This may develop further into an Empire Forestry Bureau.

The work of the different sections is described: 18 students were in attendance.

Baum und Wald. By Professor Ludwig Jost. Julius Springer, Berlin, 1936. Price 4.80 *RM*.

THIS is volume xxix of the interesting series 'Verständliche Wissenschaft'. It discusses trees and woods in a simple way, and there are many good illustrations.

Most of the book is taken up with the form, growth, and functions of the different parts of trees, broad-leaved and coniferous, and there are also brief descriptions of a virgin forest in Bohemia, and silvicultural systems.

FAUNA AND FORESTRY IN GREAT BRITAIN

BY WILLIAM LING TAYLOR

MAN has always taken liberties with nature. At an early stage in his development he was forced to clear and till the ground to supplement his food supply, and the day the first spit was turned witnessed the insertion of the first puny lever beneath the balance of nature. This lever has grown in power until at the present time dense populations, raised and assembled under artificial conditions, have to be fed, clothed, housed, and amused. To enable this to be done, large tracts of the five continents have been cleared, drained, and cultivated; natural growths have gone or have suffered modification, and wild animals have been killed out, driven off, or forced to modify their habits. In general, the balance of nature is hopelessly upset wherever man penetrates, and nowhere is the disturbance more complete than in the island of Great Britain. The primeval forests have gone entirely; woods have been cleared and grubbed up, and land has been enclosed, drained, and cultivated until there are few if any spots left to us that can be said to remain wholly in their natural state, uninfluenced by the work of man. Industry has also left, and is leaving, its indelible mark on large tracts of England, Wales, and Scotland.

The reactions of all this change upon the wild life of the country are, of course, profound and have been continuous. Further to complicate matters alien species have been acclimatized. Thus we gained at an early date the pheasant, the rabbit which was introduced some 900 years ago, the grey rat, the red-legged partridge, and more recently the little owl, the grey squirrel, and the musk rat, a new-comer which has only been suppressed at the cost of considerable trouble. It is probable that others of the fur-bearing species farmed in this country are also at large, such as the coypu (nutria), the mink, and the silver fox, but none of them has yet established itself as a breeding species so far as is known. The Japanese deer, the barking deer, and the Chinese water deer have, however, so established themselves.

Of our far richer early fauna there is nothing to be said. It has gone and only paleontological traces remain. The beaver, boar, and wolf were killed out in comparatively recent times; the last great auk in existence was killed about a hundred years ago, and we have lost the spoonbill, the great bustard, the white-tailed eagle, and the osprey, the last mentioned having finally disappeared from Scotland as a breeding species only about twenty-five years ago. The capercailzie died or was killed out, but was successfully reintroduced in the course of the early nineteenth century. We have to thank the game laws and the gamekeeper for the survival of the ptarmigan, grouse, blackgame, pheasant, and partridge, and the latter is certainly not to blame for the infrequent appearance of the quail. On the other side of the account, however, it is beyond dispute that the continuous and ill-directed persecution of our remaining

carnivores and raptores is responsible for the reduction to mere localized remnants of the marten, wildcat, polecat, kite, bittern, and the harriers.

The badger, fox, otter, stoat, and weasel hold their own, and so more or less do the peregrine falcon, buzzard, kestrel, sparrowhawk, merlin, the rarer hobby, the owls, and the raven. They do so in spite of continuous persecution. Foxes enjoy tacit protection in any hunting country, though not elsewhere. The red deer is generally protected, and of the larger native land fauna only perhaps the badger, otter, roe deer, and, in non-hunting country, the fox can be said to have maintained themselves satisfactorily and unaided in truly feral conditions. That they have managed to survive is excellent evidence that they may continue to do so. The omnivorous badger is certainly a useful denizen in the forest although his respect for rabbit fencing is not always what it might be. Small, isolated, herds of 'wild' goats have also managed to maintain existence; in their small numbers they are both inoffensive and unoffending.

The most potent influences on the fauna of Britain in the past two hundred years have been the enclosure of land, the spread of population, and the preservation of game. Of these the first two have restricted habitat, and the third by reason of the indiscriminate killing of 'vermin' has given to the destructive rodents, i.e. hares, rabbits, squirrels, rats, voles, and mice, the opportunity to increase and multiply. It is high time that owls and hawks were given a respite. Even the much abused and alien little owl has been proved to include the pine weevil in its diet. On the other hand, it is to be remembered that interest in sporting has almost certainly preserved the native and introduced game birds, the wild red deer, and also the fox over considerable parts of England.

Efforts have been made to calculate the annual net cost of harbouring our rabbits and hares, and the yearly losses from rats, voles, and mice, but the fact is that these losses are as incalculable as they are prodigious. The red squirrel can, without any doubt, be the consequence of serious loss in the woods, and the grey squirrel, should it develop into a widespread forest pest as it has already into a garden pest, is also to be reckoned with in considering the enormous losses to husbandry from rodents which, hitherto, generally appear to have been viewed with something approaching complacency. There are also the losses arising from the ravages of the larvae of certain of the coleopterous and other insects which have their place in the normal menu of the badger, fox, buzzard, kestrel, and owls.

Forestry is a branch of husbandry that has received a considerable fillip in Great Britain since the publication of the Acland Report at the close of the Great War, and foresters cannot remain altogether blind to the position into which our native fauna has drifted. The depredations of ground game, deer, squirrels, rats, mice, and voles, not to mention insects, are very serious matters in forest economy, although the aggregate losses are a flea-bite in comparison with those inflicted upon agriculture by the same agents. Surely the most rational remedy lies in an attempt to adjust the relative numbers of the helpful predatory species to the non-predatory. Given the opportunity, any species

will increase and maintain itself to the extent of its available food supply, the only other limiting factors being its natural enemies and disease. It is, however, clearly impossible, in the conditions in which we live in this year of grace, 1937, to allow nature suddenly to have full sway with regard to our fauna. There are conflicting interests, and foresters must be good neighbours. To take a simple instance: it is manifestly unreasonable to encourage a large fox population however tiresome and costly the local rabbits and voles may also be. Foxes will not always content themselves with the 'small deer' of the country-side when the game covert and poultry yard are at hand. The regulation of a forest fauna must be undertaken in a spirit of reasonableness and consideration, but is it not true that the interests of the agriculturist in these matters are closely identical with those of the forester? On broad lines the farmer's animal foes are much the same as the forester's and his losses are infinitely heavier. The trouble is that the depredations of the rodents are less obvious to him than the result of a raid by reynard or a hawk. Besides, the fox affords sport and the rabbit both sport and (apparent) profit.

Any attempt to readjust the balance of our fauna is properly a matter for all interested in husbandry, and there is a considerable volume of animal ecological research to assist. There is, however, much that forestry can do for itself. In the first place all sizeable woods however they be treated afford some degree of sanctuary to wild creatures and are a valuable safeguard against the final killing out of any further species. Secondly, the relative numbers of any species can be regulated within the forest. Thirdly, the forester is the most consistently active foe of the rabbit, and fourthly, it is safe to say that it is in the forester's hands to save the native pine and beech martens and the polecat from extinction, and to preserve the wildcat from a similar fate. Forestry may also aid the kite in its last struggle to maintain itself as a British species and may be the means of inducing the osprey to return and nest. The marten is a foe to the squirrel, and in reasonable numbers is to be welcomed in the forest. Both the marten and the polecat are perilously close to extinction in Britain, and the beech marten may already have been finally lost. What is seldom remembered until too late is that extinction of a species or race means that it is lost for all time. The wildcat has to some extent increased its numbers of late years in its only habitat, the Highlands as far south as Perthshire, but it is all too easy an animal to trap, and its position is far from being secure. It will be a calamity to natural history if the British race of the species *Felis catus* is permitted to become lost.

Extensive afforestation such as is proceeding at present may, and almost will, result in changes in the local fauna. In part these changes will be temporary and sometimes sudden. The killing out of rabbits over several thousand acres has been known to drive part of the stoat and weasel population farther afield, and enclosure and afforestation have resulted in different parts of the country in influxes of foxes or of deer. It is quite plain that where abnormality occurs excessive numbers must be reduced. The circumstances require study and will repay proper investigation. It is a rule of good forestry, particularly where

new forests are being created, that the forester shall be acquainted with the fauna of the locality and of his forest. Without intimate knowledge of the animal populations and their changes it is impossible to take the steps that are bound to become necessary following any major alteration in the utilization of land to induce a balance of nature suited to the circumstances. Too many foxes are an offence to the neighbourhood, too many deer a danger to the woods and the farmer, and too many nesting crows, hawks, and wood pigeons cause trouble all round; but the rarer hawks should be spared until their future as native species is assured.

A word may be said regarding deer. Our native deer are red and roe. The status of fallow deer is doubtful, and it is generally assumed that the present stocks of this species are either semi-domesticated park deer or the progeny of escapes from deer parks, and have been introduced from early historic times onwards. To these must be added the more lately acclimatized Japanese and water deer and possibly yet other kinds, for further species are kept in parks and escape from time to time. Our native deer (as well as fallow deer) are all woodland animals in spite of the fact that red deer now mainly inhabit mountain country to which they have been forced by the encroaching cultivator. There is a far greater sporadic population of deer of the different species throughout the country than is generally recognized, and there are not many of the larger woods without a few head of deer. In the sanctuary of the larger forests it does not take many years for a few head to increase their numbers to the dimensions of a herd. Deer of all kinds do persistent damage in woodlands, and periodic reductions in numbers have to be made, but if one thing is more certain than another, it is that the new forests now being planted will render our native roe deer, as well as other established species, safe from possibility of extinction.

To sum up:

1. The incidence of the various species amongst themselves is very imperfectly understood and requires systematic study.

2. Foresters have it in their power, possibly to a greater degree than any other section of the community, to effect gradually and reasonably, if locally, a salutary adjustment of the balance of our fauna.

3. They can by such reasonable regulation acquire a measure of natural control over rodent and other pests other than by the present costly methods of forest protection, a control which will be of benefit to husbandry throughout the neighbourhood of the forest.

4. They can prevent further depletion of our rarer native species, and they can preserve the remnants of three most interesting British mammals that are within measurable distance of extinction. It may also be that there is yet time to save the kite as a breeding species.

Lastly, by the suppression of excessive numbers of any injurious species they can prove themselves good neighbours, and by protecting those species whose numbers are weak, they can also achieve a step forward in a branch of the preservation of rural Britain that is too often ignored, i.e. the protection of our natural fauna.

THE DISTRIBUTION, STRUCTURE, AND PROPERTIES OF TENSION WOOD IN BEECH (*FAGUS SILVATICA* L.)

BY S. H. CLARKE

(Forest Products Research Laboratory, Department of Scientific and Industrial Research)

INTRODUCTION.

AN interesting difference between softwood and hardwood trees is that, whereas horizontal or leaning stems of the former are epitrophic, those of the latter are hypotrophic (10); that is, in response to the stresses developed in stems out of the vertical, softwoods develop 'compression wood' (*rotholz*) on the lower sides, whereas hardwoods develop 'tension wood' (*weissholz*) on the upper sides of the stem. The structure and properties of compression wood have been dealt with at length in the relevant literature (the fullest account is that of Pillow and Luxford, 7), but little appears to have been written about the hardwood counterpart, beyond that in this tissue the secondary walls of the fibres have a gelatinous appearance, and are of the type sometimes known as 'tertiary fibre walls'. The nature of the fibre walls has a profound influence on the strength of timber (2, 3), and a study of tension wood was undertaken in order to throw further light on factors influencing the mechanical and physical properties of wood.

English beech (*Fagus silvatica* L.) was selected as a subject for investigation because this species is very prone to the formation of gelatinous fibre walls, and because a large body of data was available in the laboratory for comparative purposes. The choice proved to be a happy one. Trees were found in which tension wood was strongly developed and easily recognized, thus facilitating a comparison of this tissue with normal wood.

In the material examined, tension wood usually occupied about one-third or more of the circumference of the growth rings in which it was found; the remainder of the wood was apparently all of one type, and accordingly throughout this paper it is referred to as 'normal wood'. Microscopic examination confirmed that the secondary walls of the fibres of the tension wood had a distinctly gelatinous appearance, and that they were apparently unlignified, or less strongly lignified than those of normal wood; in order to avoid unnecessary implications as to their nature or composition they are designated 'tension wood fibres' in the following pages.

MATERIAL AND METHODS.

The requisite material for the investigation was obtained from two separate localities. Both were on hill-sides, and before the trees were felled the sides facing uphill were marked with a scribe.

Three trees (Consignment No. 280) were from the side of a cutting near

Kingston Blount, Oxon. Two of these overhung the margin of the cutting, and grew in a leaning position; the boles were of the type known as 'hanging', 'pistol-butted', or 'sabre-butted'. The third (Plate III, fig. 2) was one of a trio of shoots from a single stool; it had an almost corkscrew-like twist, and was of especial interest for studying the distribution of tension wood. At breast height the trees were $5\frac{1}{2}$, $4\frac{1}{2}$, and $7\frac{1}{2}$ inches quarter girth respectively; and they were healthy and not suppressed.

Two larger trees, of $9\frac{1}{4}$ and $12\frac{3}{4}$ inches breast height quarter girth respectively, were obtained from a hill-side near Stroud, Glos. They formed part of Consignment No. 272. Plate III, fig. 5, shows part of the hill-side and gives some idea of the spacing and dimensions of the trees; one of the selected trees is marked (*a*) in the photograph, and against it is leaning a 9-foot rod. The trees showed evidence of having been pistol-butted in youth, but this feature was becoming obscured by the balancing effect of the growth layers laid down in the course of years.

Cross-sectional disks 1 inch in thickness were taken from various heights in the trees for the study of the distribution of tension wood, and others of appropriate thickness were cut for the preparation of test specimens. The maximum crushing strength under compression parallel to the grain, toughness (as measured by the pendulum test), tensile strength along the grain, specific gravity (oven dry weight/green volume), and moisture content at the time of test were determined by the Timber Mechanics Section. Unstressed portions of the test pieces were used later to determine the shrinkage of the wood in drying.

RESULTS AND DISCUSSION.

(*a*) *The Distribution of Tension Wood.*

In almost every instance the disks were eccentric, owing to the greater growth on the tension side of the stem. As the disks dried out the tension wood became distinguishable on the end-grain as a silvery zone, rather more lustrous than the remainder of the surface. After brushing the surface of the disks with a solution of phloroglucin in hydrochloric acid, the tension wood was even more clearly differentiated as a silvery pink against the dull, deep red of the normal wood (Plate IV, fig. 6).

All the trees were consistent in that, so far as could be ascertained, wherever tension wood occurred it was on the upper, or tension, side of the pith. The majority of disks from sloping parts of the tree (i.e. particularly near the base) were eccentric, the tension side being the wider. As the trunks approached the perpendicular the pith usually approached an axial position, and tension wood was less strongly developed.

In the upper disks of the larger trees the distribution of tension wood was not so easily explained. In some disks it occurred on all radii, though no instances were observed of its presence in all parts of the same annual ring; such an arrangement might well be due to changes in the tension, or in the vertical arrangement of the stem, accompanying changes in crown development. It

was, of course, impossible to say what conditions obtained at the time of production of the tension wood in the earlier life of the tree.

The name 'tension wood' was originally applied on the assumption that the tissue is laid down to meet, or in response to, the special tensile stresses developed in leaning stems. It has been demonstrated (5), however, that this type of tissue may be induced on the upper side of non-vertical stems irrespective of whether they are in tension or compression at the critical points, and it has been suggested (1, 8) that gravity is the responsible stimulus. The distribution of tension wood in the trees now described might have been explained by either hypothesis. The distribution of tension wood fibres within a single growth ring is, however, of some interest in this connexion. It may be observed (Plate III, fig. 1) that during a single year a particular set of cambial initials may give rise to alternating tangential zones of tension wood fibres and normal fibres. Evidently the conditions influencing the production of tension wood fibres may change several times during a single growing season. Such alternations were not observed in the middle of zones of well-developed tension wood, but only at the margins of these zones, and it would appear that in such transitional regions response to changes in the degree of tension, or in the angle of inclination of the stem, is fairly rapid.

(*b*) *The Microscopic Structure of Tension Wood.*

The most striking characteristic of tension wood as revealed by the microscope is the peculiar nature of the secondary walls of the fibres. With standard microstains and reagents these give the reactions typical of so-called non-lignified walls, in contrast to the reactions of the secondary walls of the fibres of normal wood. A description of the staining reactions of this type of fibre has already been given (3, p. 146). The distribution of the tension wood fibres in the present material coincided with the silvery zones of tension wood observed macroscopically on the surfaces of the disks. Such fibres were found chiefly in the earlier parts of the growth rings, and never among the last few rows of cells of the year's growth.

A comparison of the length of tension wood fibres with that of fibres from the opposite side of the same annual ring was indeterminate, since although in some trees the tension wood fibres were slightly the longer, there were several exceptions.

(*c*) *Machining Properties.*

During the preparation of test specimens in the Section of Woodworking the opportunity was taken of observing the machining properties of tension wood.

When worked in the lathe it was observed that the turnings from the tension wood samples came off in long, unbroken, rather pliable ribbons, whereas those from the normal samples came off in short, broken chips which were inclined to be brittle.

On the rotary planing-machine tension wood took a distinctly more woolly

finish than normal wood, particularly where the cutters worked against the grain. The specimens were prepared in the green condition and the woolliness became more noticeable as they dried out. The tendency of fibres of this type to tear out rather than to cut smoothly has been noted previously (3). So marked was the tendency in the present material that it was possible in most cases to recognize the tension wood specimens solely by their woolly finish.

(*d*) *Shrinkage.*

The investigation of shrinkage was carried out on the material of Consignment No. 280 only. As the results obtained were in agreement with earlier observations (3) it was considered unnecessary to seek further confirmation by a detailed study of Consignment No. 272.

The dimensions of the test specimens were measured in the green, and again in the oven-dry conditions, and shrinkage was computed as a percentage of the green dimensions. The results are plotted against specific gravity in Plate IV, fig. 7. There it may be observed that radial shrinkage was not related to specific gravity, and the shrinkage of the tension-wood specimens was of the same order as that of the remainder; there was, however, a distinct, non-linear relation between specific gravity and shrinkage in the tangential direction, and on the whole the tension wood shrank rather more in the tangential direction than the normal wood of similar specific gravity. In Plate IV, fig. 8, longitudinal shrinkage is plotted against specific gravity, and it is apparent that the shrinkage of the tension wood was much greater than that of normal wood. The influence of the fibre-walls on shrinkage would appear to be established, and it is of interest that the view, once widely held, that 'tertiary fibre-walls' influence the hygroscopicity of wood and 'prevent undue shrinkage and swelling' (6), is contradicted by the observations now recorded.

(*e*) *Strength under Compression parallel to the Grain.*

Without exception, specimens with strongly developed tension-wood fibres were very weak under compression parallel to the grain, irrespective of their specific gravity. The extent of the influence of fibres of this type on strength has been dealt with at length in an earlier paper (3). All the specimens were tested to complete failure, and it was noticeable that the majority of the tension-wood specimens failed by buckling (Plate III, fig. 3), whereas the majority of the normal specimens showed a shear type of failure (Plate III, fig. 4). This is in keeping with the general observation of the Section of Timber Mechanics that on the whole the buckling type of failure tends to be more common in timbers that are below the average in compressive strength for their density.

(*f*) *Toughness.*

Unfortunately, the rather irregular grain and the small size of the trees of Consignment No. 280 limited the number of toughness test-pieces that could be prepared. A sufficient number were available, however, to indicate clearly that tension-wood fibres do not decrease the toughness of a specimen as they

do strength under compression parallel to the grain. The larger trees of Consignment No. 272 permitted a closer comparison of tension and normal wood. The mean specific gravities of the tension-wood and normal-wood specimens of these trees were 0·603 and 0·615 respectively, and the toughness 165 and 147 inch-pounds respectively. The indication that tension-wood specimens were on the average slightly stronger than normal specimens is further borne out by Plate IV, fig. 9, in which it may be seen that at any specific gravity the average toughness of the tension-wood specimens was usually slightly higher than that of normal wood.

The evidence of both consignments of timber indicates that, although tension wood is much weaker under compression parallel to the grain than normal wood of the same density, it is not essentially weaker, and may even be slightly stronger in toughness. This observation is of interest from two points of view: in the first place it is in agreement with a conclusion reached during a study of the properties of ash timber (2), namely, that whereas strength under compression parallel to the grain appears to be closely linked with the secondary walls of the wood fibres, toughness depends rather on the primary wall and middle lamella; and in the second place, accepting Potter's suggestion (9) that tertiary fibre-walls represent an arrested stage of development, the observation is in agreement with the hypothesis that during growth the cell-walls of wood may undergo some change that brings about an increase in compressive strength but a decrease in toughness (4).

(*g*) *Tensile Strength.*

The dimensions and shapes of the trees of Consignment No. 280 did not permit the preparation of specimens for testing the strength in tension parallel to the grain. Standard specimens were prepared, however, from a portion of one of the trees of Consignment No. 272, for comparing the tensile strength of tension and normal wood. The results of the tests showed a very wide range of variation for both types of wood. On the average, however, the tension wood was stronger than normal wood of the same specific gravity (Plate IV, fig. 10), and whereas the mean specific gravities of the specimens of tension and normal wood were approximately the same, namely 0·62, the tensile strengths were 21,800 and 19,800 lb. per square inch respectively.

It was observed that the splinters of the fractured tension-wood specimens were much more woolly than those of normal wood.

CONCLUSIONS.

Whatever the ultimate cause of formation of the tissue generally known as tension wood, it appears to be developed normally on the upper side of leaning stems of beech trees, and any inclination of the trunk may have an appreciable influence on the properties of the wood. The influence of sloping sites is the more important since the tension side of the tree is usually the wider.

The exceptional weakness of tension wood under compression parallel to the grain is probably of little importance from the practical viewpoint, since the

dimensions in which beech is normally used are more than sufficient to offset any reduction in strength resulting from the presence of tension wood. In toughness and tensile strength the tissue compares favourably with normal wood.

The shrinkage and woodworking properties are, however, worthy of particular note. Tension wood is on the whole more woolly than normal wood, and under certain circumstances the woolliness may be so pronounced as to constitute a distinct defect. Again, tension wood shrinks much more along the grain than normal wood, and is likely to cause distortion and splitting in sawn timber and manufactured goods unless due precautions are taken in the selection of material.

The investigation has been successful in establishing some practical connexion between the inclination of the trunks of beech trees and the structure and properties of the timber produced. It is perhaps of equal importance, however, in bringing from new angles support for the hypothesis that strength under compression parallel to the grain is more closely dependent on the nature of the secondary walls of the fibres than is toughness, and that probably some factor tending to increase strength in compression tends at the same time to decrease the toughness of wood.

SUMMARY.

In the five trees examined, tension wood was present on the upper sides of non-vertical parts of the trunks; it was distinguishable by the naked eye on cross-sectional disks. Microscopically, the chief peculiarity of tension wood is the gelatinous appearance of the secondary walls of the fibres, which react with the so-called cellulose stains and reagents.

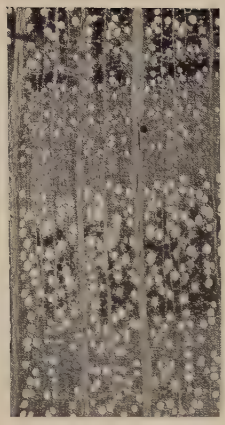
Compared with normal wood of equal density tension wood was found to be exceptionally weak under compression parallel to the grain; in tensile strength and toughness, however, it was on the average slightly stronger than normal wood of the same density.

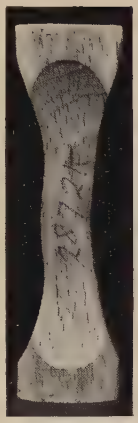
In drying from green to oven dry, tension-wood and normal specimens shrank more or less equally in the radial direction; in the tangential direction the tension wood shrank rather more than normal specimens of equal density; in the longitudinal direction the shrinkage of the tension wood was abnormally high.

In the lathe, turnings came from tension-wood cylinders in long, pliable pieces, but those from normal wood were more brittle and broke into small chips. When surfaced on a rotary planer the tension wood was inclined to be woolly where the cutting went against the grain.

ACKNOWLEDGEMENTS.

The author is indebted to Mr. W. A. Robertson, Director of Forest Products Research, for permission to publish this article, to his colleagues in the Timber Mechanics Section for their co-operation, and to Mr. G. L. Franklin for the preparation of material for microscopic examination.





1 2 3 4

a

5

PLATE III

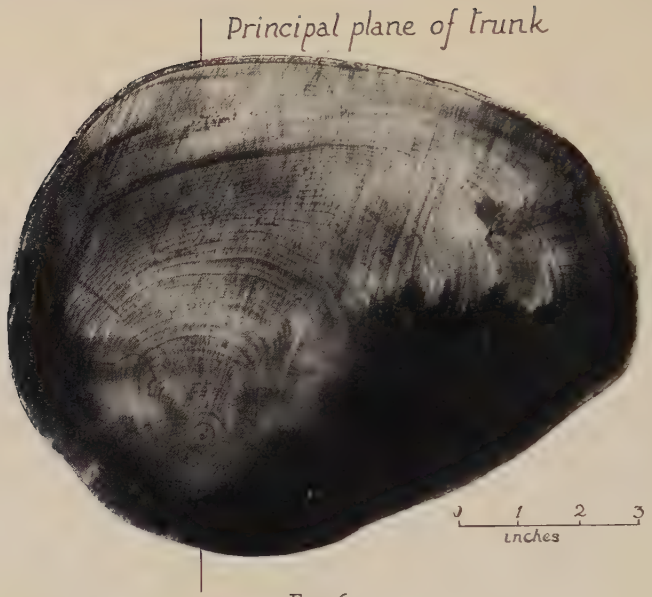


FIG. 6

COMPARISON OF TENSION WOOD AND NORMAL WOOD IN ENGLISH BEECH

● = TENSION WOOD FIBRES PRESENT
○ = TENSION WOOD FIBRES ABSENT

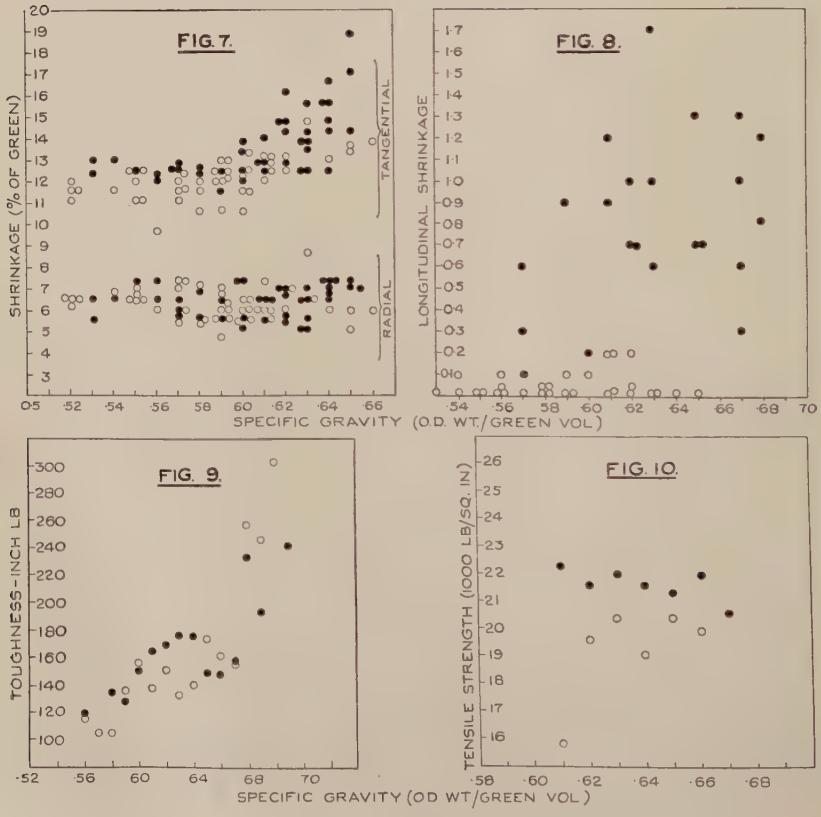


PLATE IV

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THE INFLUENCE OF CERTAIN ACCESSORY FACTORS ON FROST INJURY TO FOREST TREES[1]

BY W. R. DAY and T. R. PEACE

IV. AIR AND SOIL CONDITIONS

Air Movement and Humidity

The Problem.

THE influence of wind on frost injury has already been discussed (vol. x (2), p. 125). It must be admitted that its significance is still far from understood. There is no doubt that wind alone can damage or even kill trees, and that the injury it causes in many ways resembles that due to frost. Obviously, therefore, it may be difficult to separate wind damage from frost injury where both have occurred, and still more to estimate the effect, if any, of wind in increasing or decreasing frost injury. The rate of evaporation from leaves is a factor which may affect the degree of frost damage, and which is largely determined by the rate of movement and humidity of the air.

In general, humidity tends to be high during frost, for the relative humidity rises as the temperature of the air falls, and the deposition of hoar-frost is an indication that the atmosphere is saturated. But during more prolonged winter frosts the humidity often falls considerably, and what is known as 'Black Frost' often occurs, where hoar-frost is more or less absent, and the dryness of the atmosphere is reflected in the gradual withering of the more susceptible parts of plants. Analysis has been made of the maximum and minimum relative humidity during 150 frosts occurring in the autumn, winter, and spring of several years at Oxford. The maximum humidity during the frost was usually 90 per cent. or more, but on 10 occasions it was below 75 per cent. and on 2 below 60 per cent. The minimum was below 75 per cent. on 44 occasions, below 60 per cent. on 11, and below 50 per cent. on 3; the lowest figure recorded being 46 per cent. Baldwin (1) has found humidities varying from 40 to 60 per cent. over the snow crust, the lowest figures occurring with the greatest air movement.

Air movement may also affect frost damage by moving the plant during freezing. Since the water surfaces in the plant are very small, movement is unlikely to prevent freezing, as would happen if a large surface of water were agitated, but rather to hasten it by preventing under-cooling. In addition, if, as may be the case, injury arises owing to ice formation within the tissues, movement of the frozen plant would be likely to make it more serious.

Previous Work.

Little work has been done on the effect of wind on plants during frost, but there is a general opinion that wind can and often does increase injury. Also

[1] Continued from vol. xi (1), p. 27.

if the soil is frozen, and the roots consequently inactive, wind is generally believed to be capable of causing injury by stimulating excessive transpiration. But these beliefs are based on general observation, rather than on experiment. A large number of investigators (vol. x (2), p. 126) have found that hardiness increased with decreased moisture content of the tissues, which suggests that up to a point evaporation, by decreasing the water content, should increase hardiness rather than cause injury. On the other hand, there is no doubt that evaporation beyond a certain point will cause excessive water loss, wilting of the tissues, and consequent damage; and this may well take place earlier if water intake by the roots is restricted by frozen soil, as often occurs in the winter, particularly in continental climates.

The movement of plants and its effect on freezing has been investigated by Harvey (5) using cabbages and tomatoes. He found that it prevented the cell-contents cooling below the freezing-point, and thus accelerated ice formation and injury. Wright and Taylor (14) found the same to hold for potatoes.

Material and Methods.

The general methods of experiment and the types of trees used have already been described (vol. xi (1), p. 14), but for convenience part of the information there given is repeated here. A small number of trees, varying from 3 to 8, but usually 4, was subjected to each treatment, and all frozen at the same temperature, usually for four or six hours. In the 1931–3 experiments and in some of those carried out in 1934 normally only one temperature was used, but in a few cases the whole experiment was duplicated at a different temperature. The use of such small numbers of trees has undoubtedly led in certain cases to contradictory results, so that the general effect of any factor should be judged by the general trend of the results of the experiments, rather than by the result of any one of them. Small trees of the following species were used: European (Eur.) larch, Japanese larch, Korean larch, Siberian larch, Douglas fir (Green variety), Scots pine, Norway spruce, Sitka spruce, *Thuja plicata*, oak, and beech. They were 2 to 5 years old and planted in pots, which were protected during experimental freezings by sawdust or by electrical heating. As a comparison between the different treatments an arbitrary percentage scale of damage is used, on the basis, undamaged 0, slightly damaged 25, moderately damaged 50, severely damaged 75, and dead 100. The figure quoted under the heading 'Damage Percentage' or DP. in the various tables is the average value for all plants in each treatment.

In part of the 1934, and in all the 1935 and 1936 experiments, all the treatments were repeated in 3 to 7 freezing temperatures separated by 1 or 2 degrees. This enabled the 'Critical Temperature' (CT.), that is the highest temperature at which half the plants were damaged, to be recorded. Thus, in the later experiments, both the critical temperature and the damage percentage can be used as a basis of comparison. In certain cases the range of temperatures was insufficient to include the critical temperature for each treatment. If the critical temperature lay below the lowest temperature used, this is indicated

by adding the letter 'b' to the temperature given; if it was at or above the highest temperature used, the letter 'a' is added.

In the experiments concerned with wind a special piece of apparatus was used, which consisted of a large box, the lid of which could be tightly closed. This box was so partitioned that a circulation of air could be obtained within it by means of an electric fan that could be run at different speeds. The plants under experiment were placed directly in front of the fan, and the box was so arranged that the air could pass over trays of calcium chloride to absorb its moisture and lower its humidity. In this way winds of different velocities and of different degrees of dryness could be obtained. The relative humidity was read on a hair hygrometer which projected through the top of the box. Actually the wind speeds which could be obtained with the fan were very low; the so-called high wind varied from 2 to 7 m.p.h. according to position and the low wind from 1 to 2 m.p.h. These being equivalent very roughly to Beaufort wind numbers 2 (slight breeze) and 1 (light air). A comparison of evaporation was made with the lid off the box, using simple evaporimeters. If the evaporation in still air is regarded as unity, the low wind gave a value of 6·1 and the high wind of 7·7.

Experimental Results.

Experiments with a more powerful fan giving wind speeds up to 16 m.p.h. and with the fan in the box already described, indicated that at temperatures above freezing the plants suffered no damage from wind alone. Any effect of the wind in these experiments, therefore, must be regarded as its influence on frost damage, not as due to the wind itself. The experiments with which we are here concerned are set out in Tables X and XI. In the first table, which is concerned with experiments where the humidity was not controlled but was never very low, we see that damage increased with wind speed in 9 experiments, that there was no effect in 1, and that in the remaining 2 the effect was reversed. Only in 2 cases is the difference reflected by a difference in the critical temperatures. In the second table, if variations in humidity are neglected, we see, from the last column but one, that damage was increased by wind in 14 experiments, that it had no definite effect in 4, and that it was decreased by wind in 5 cases.

It would seem that in general the injury due to frost is increased in the presence of wind, but that this increase is usually slight and often negligible. It is probably advisable to shelter tender plants and trees from the wind during the winter; but the shelter should be so arranged that it does not lead to the collection of pockets of cold air on still nights, when the only movement of air is that caused by the cold air flowing from high to low ground. Shelter should be arranged to block cold north and north-east winds, but should run up and down slopes, not directly across them, so that cold air can flow unobstructed downhill on still nights.

The effect of the humidity of the air, as can be seen from the last column in Table XI, is very indefinite; in 10 experiments damage increased with humidity, in 12 the reverse was the case, while in 1 there was no effect. As can be seen

TABLE X. *Effect of wind (humidity not controlled)*

Year.	Date.	Species.	Frozen at.	Damage percentage.			Critical temperature.		
				High wind.	Low wind.	None.	High wind.	Low wind.	None.
1935	18–21 Jan.	Thuja	11, 14, 15, 17, and 19° F.	35	25	..	17° F.	17° F.	..
1933	1–2 Feb.	Scots pine	15° F.	94	94	94	..	..	..
1934	8–12 Feb.	Thuja	13, 15, 17, 19, and 21° F.	19	..	14	17° F.	..	17° F.
1934	2–5 Mar.	Thuja	13, 15, 17, 19, and 21° F.	43	..	35	19° F.	..	17° F.
1935	4–8 Apr.	Sitka spruce	14, 15, and 17° F.	57	48	..	17° F. a	17° F. a	..
1934	10–13 Apr.	Sitka spruce	15, 17, 19, and 21° F.	34	..	5	19° F.	..	15° F.
1931	22 Apr.	Eur. larch	21 and 22° F.	56	..	66	..	..	..
1933	1 May	Sitka spruce	22° F.	62	..	70	..	..	..
1931	5 May	Eur. larch	24° F.	47	..	22	..	..	..
1934	12–16 May	Sitka spruce	21, 23, 25, and 27° F.	62	55	..	25° F.	25° F.	..
1935	4–7 June	Norway spruce	22, 23, 25, and 27° F.	47	44	..	25° F.	25° F.	..
1931	12 June	Oak	25° F.	75	..	62	..	..	..

TABLE XI. *Effect of wind and humidity*

Year.	Date.	Species.	Frozen at.	Humidity percentage range.		Damage percentage.						Increase of damage by	
				Humid.	Dry.	HH.	HL.	HN.	DH.	DL.	DN.	Wind.	Humidity.
1933	23–27 Feb.	Scots pine	14° F.	87–93	30–57	44	88	56	37	75	37	?	Yes
1933	9–10 Mar.	Scots pine	17° F.	91	28–40	81	44	..	69	44	..	Yes	Yes
1932	8–15 Mar.	Sitka spruce	14 and 15° F.	71–88	29–35	42	..	..	57	12	..	Yes	No
1932	20–24 Mar.	Douglas fir	19° F.	84–94	40–58	58	67	47	58	58	42	?	Yes
1933	22–24 Mar.	Eur. larch	14° F.	91	25–36	75	56	..	75	75	..	Yes	No
1933	22–24 Mar.	Scots pine	14° F.	91	25–36	25	12	..	25	44	..	No	No
1932	5–12 Apr.	Eur. larch	20 and 24° F.	85–96	30–45	71	58	..	83	42	..	Yes	Yes
1933	7–8 Apr.	Scots pine	17° F.	90–2	20–45	62	31	..	31	44	..	Yes	Yes
1932	21–23 Apr.	Sitka spruce	18 and 20° F.	92	35–6	79	71	..	79	71	..	Yes	Equal
1932	30 Apr.–3 May	Norway spruce	21 and 25° F.	99–100	50–72	42	42	..	17	46	..	No	Yes
1932	30 Apr.–3 May	Oak	21 and 25° F.	99–100	50–72	25	0	..	42	33	..	Yes	No
1933	5–7 May	Norway spruce	21° F.	90–4	44–58	87	62	..	72	50	..	Yes	Yes
1932	10–12 May	Beech	23° F.	90–2	30–4	25	25	..	50	42	..	Yes	No
1932	10–12 May	Eur. larch	23° F.	90–2	30–4	58	8	..	58	50	..	Yes	No
1933	10–13 May	Sitka spruce	23° F.	91–6	42–77	62	56	56	..	69	56	Yes	No
1933	10–13 May	Eur. larch	23° F.	91–6	42–77	62	12	25	..	37	44	No	No
1933	18–19 May	Sitka spruce	24° F.	95–6	40–2	37	56	..	50	56	..	No	No
1933	18–19 May	Eur. larch	24° F.	95–6	40–2	75	37	..	25	69	..	No	Yes
1932	19–24 May	Norway spruce	22 and 24° F.	92–8	50–62	69	35	40	60	54	..	Yes	No
1932	19–24 May	Eur. larch	22 and 24° F.	92–8	50–62	75	25	79	62	54	..	Yes	No
1932	7–9 June	Norway spruce and Eur. larch	24° F.	92–8	38–55	72	..	59	53	66	..	?	Yes
1932	10–14 June	Eur. larch, Norway spruce, and Douglas fir	24° F.	92–9	58–85	0	50	5	65	35	0	?	No
1932	10–14 June	Oak	24° F.	92–9	58–85	42	25	0	58	0	0	Yes	Yes

HH. = High wind, humid atmosphere.
HL. = Low wind, humid atmosphere.
HN. = No wind, humid atmosphere.
DH. = High wind, dry atmosphere.
DL. = Low wind, dry atmosphere.
DN. = No wind, dry atmosphere.

from the ranges given in the table, the humidities for the dry atmosphere were often lower than those normally occurring in nature. There is a suggestion that in May and June, when the trees are in fresh leaf, dry air does often increase injury, whereas in the earlier part of the year humid air does so, possibly because the plants are damp, which, as will be seen in a subsequent section, slightly increases damage. But there is no definite division, and experiments occurred in May and June in which humid air increased injury and during March and April in which dry air did so. The duration of freezing in these experiments was six hours, and it is quite definite that over this length of time the humidity of the air had very little effect on the amount of frost injury. It is quite possible that frosts of longer duration might have more effect.

Only one experiment was carried out on the movement of plants during freezing. A number of Japanese larch was frozen at 20, 21, 22, 23, 25, and 27° F. on 17–19 May 1934. In each temperature half the plants were continually agitated by means of an electric motor working a rocker arm to which the trees were attached, while the other half were left as controls. The shaken trees had a critical temperature of 25° F. as compared with 23° F. for the controls and a damage percentage of 60 as compared with 42 for the controls. As would be expected from other workers' results, shaking increased damage. This is another reason for providing shelter from wind wherever possible.

Dry or Frozen Soil, and Defective Root Systems

The Problem.

We are concerned here with a large number of factors, which include the dryness of the soil, the condition of the roots and their ability to absorb water, and the effect of frozen soil on the ability of the plant to withstand not only freezing but also drying winds during the winter. It is obvious that all these factors may occur in nature, and most of them can be controlled to some extent by artificial means. The soil cannot be dried at all easily, but it can be moistened. Transplanting, or digging, as well as such natural phenomena as drought, waterlogging, or insect attack may well affect the condition of the roots. The freezing of the soil can be modified or even prevented by soil coverings, and the amount of transpiration from plants in frozen soil can be lessened by suitable shelter.

Two effects appear to be concerned here, firstly, that of water absorption on the amount of water in the plant and, therefore, on the frost injury to it (see vol. x (2)), and, secondly, that of excessive transpiration when soil water is not readily available. The second only enters into these experiments when we are considering transpiration and frozen soil. In all the others, controls indicated that lack of water, pruning of roots, or freezing of the soil alone, was in no way detrimental to the plants, unless accompanied by frost injury.

Previous Work.

In general, plants growing on a dry soil are considered to be hardier than those on wet sites. Sorauer (12) states that plants in dry soils are less damaged

by frost than those in wet, because there is less water in the tissues. Korstian (6) found that on drier sites sap density was greater, and he is inclined to associate high sap densities with increased frost hardiness. Steele, Waldo, and Brown (13), working with strawberries, found that those grown in a medium dry soil were less damaged by frost than those grown in well moistened or wet soils. Lott (7), using blackberries, found that they were less damaged by frost when grown in conjunction with a cover crop. This he attributed to the cover crop using water which would otherwise have been available to the blackberries. On the other hand, McCool and Millar (9) found that the freezing-point lowering of the tops of plants was not much affected by soil moisture, though for the roots it did rise in dry soil. Salmon (11) found less frost injury to wheat and rye on wet soils, but this he attributes to a lag in the temperature fall over the wet ground. He also found that disturbing the roots of wheat and rye as in transplanting had no effect on subsequent frost damage.

Experimental Results.

The results of experiments on the condition of soil and roots are set out in Table XII. None of the treatments would appear to have had any definite effect as compared with the controls. In many cases there appear to have been differences in injury, but these are almost certainly haphazard, for in some cases the treated trees are more injured than the controls and in others less. There seems, therefore, no reason to suppose that temporarily dry soil or pruning of the roots has any marked effect on subsequent frost injury, but it must be admitted that further experiments are required before this can be stated with certainty. But there is no reason to avoid moving plants before frost, in case it should increase the injury to them.

TABLE XII. *Soil and root conditions*

Year.	*Date.*	*Species.*	*Frozen at*	*Damage percentages.*						
				A.	*B.*	*C.*	*D.*	*E.*	*F.*	*G.*
1933	9–10 Jan.	Sitka spruce	12° F.	17	4	..	29	..	..	..
1933	11 Mar.	„ „	13° F.	19	19	19	19	..	..	..
1933	1 May	„ „	22° F.	71	71	67	63	58	..	..
1931	6–7 May	Eur. larch	22 and 25° F.	38	56	..	..	..	..	..
1931	8 May	„ „	24° F.	6	..	..	..	31	12	17
1931	1 June	Eur. larch and Siberian larch	23° F.	58	..	..	67	..	..	..

A. = Untreated.
B. = Repotted just before freezing.
C. = Repotted in dry soil just before freezing.
D. = Repotted just before freezing after the roots had been severely pruned.
E. = Soil heavily watered before freezing.
F. = Soil rather dry before freezing.
G. = Soil very dry before freezing.

In Table XIII are set out the experiments on the effect of freezing the soil on subsequent frost injury. In all but the last, the soil was only just frozen and was kept just below freezing-point, while the tops were subjected to lower temperatures. In two experiments this had no effect. In the third the plants in frozen soil were rather less damaged; but this is probably due to the slight hardening effect of the period in the refrigerator, during which the roots were being frozen. In the fourth experiment (starred in the Table) the plants with frozen roots were much more damaged, but in this instance the temperature of the soil was allowed to fall as low as that of the tops and it is probable that the roots were damaged.

A number of experiments were carried out in the early spring, using Scots pine, Sitka spruce, Norway spruce, and *Thuja*, of which the tops were exposed to warm dry wind while the soil around the roots was frozen. The relative humidities used lay between 27 and 35 per cent.; the periods for which the trees were exposed to these conditions varied from four to thirty hours. In no case was any injury caused. It seems, therefore, that damage caused by excessive transpiration to trees with roots in frozen soil cannot be serious, unless it takes place over a very long period, or unless climatic conditions are more extreme than in the experiments under discussion. There seems no reason normally to try and protect the soil in the hope of thus benefiting the plant as a whole.

TABLE XIII. *Effect of freezing soil*

				Damage percentage.		*Critical temperature.*	
Year.	*Date.*	*Species.*	*Frozen at.*	*Roots frozen.*	*Not frozen.*	*Roots frozen.*	*Not frozen.*
1935	11–14 Jan.	Norway spruce	10, 12, and 14° F.	30	32	14° F. a	14° F. a
1934	8–9 Mar.	Sitka spruce	10, 11, and 13° F.	6	17	10° F.	11° F.
1935	31 Mar.–3 Apr.	Norway spruce	10, 14, and 16° F.	65	69	16° F. a	16° F. a
1933	14–15 May	Thuja	24° F.	56*	34	..	..

* The pots in this case were not protected during the final freezing.

Wetting the Leaves before Freezing

The Problem and Previous Work.

In nature, rain may occur before, or much more rarely during frost. It is of interest to know what effect this will have on frost damage. Of more practical importance is the question of spraying during frosty weather. It is necessary to know whether in doing this one is increasing the risk of frost injury to the plant.

Practically no work has been done on this question. Korstian (6) notes that wet shoots are more damaged than dry. While Harvey (5), working with

cabbages and tomatoes, states that drops of water on leaves increase damage by initiating freezing and thus preventing the undercooling of the plant sap.

Experimental Results.

The results of the experiments on this factor are set out in Table XIV. Considering for the moment only spraying before freezing, it will be seen that in nine experiments this increased frost injury (Plate V, fig. 1), while in three experiments the reverse was the case. In all three experiments where the plants were sprayed during freezing the sprayed plants were more injured than the controls. In the four experiments where critical temperatures can be estimated the difference was negligible or very small. Spraying may, it seems, increase frost injury slightly, and it is probably best to avoid spraying during frosty weather as far as possible.

TABLE XIV. *Effect of spraying plants*

				Damage percentage.			*Critical temperature.*	
Year.	*Date.*	*Species.*	*Frozen at.*	*Un-sprayed.*	*Sprayed before freezing.*	*Sprayed during freezing.*	*Un-sprayed.*	*Sprayed before freezing.*
1932	16 Nov.	Scots pine	20° F.	67	55	..	..	..
1932	12–16 Dec.	„ „	17 and 20° F.	8	17	..	..	..
1934	1–2 Feb.	„ „	11, 13, 15, and 17° F.	17	30	..	13° F.	15° F.
1934	5–9 Mar.	Eur. larch	9, 10, and 13° F.	22	28	..	10° F.	10° F.
1933	27 Mar.	Sitka spruce	14° F.	37	31	66	..	..
1934	29–30 Mar.	Norway spruce	13, 14, and 16° F.	8	21	..	14° F.	14° F
1933	13 Apr.	Eur. larch	21° F.	25	47	59	..	..
1931	2 May	„ „	23° F.	31	62	..	..	..
1934	12–16 May	Sitka spruce	21, 23, 25, and 27° F.	55	64	..	25° F.	25° F.
1932	13 May	Eur. larch	18 and 23° F.	67	56	..	..	..
1933	20 May	„ „	25° F.	0	56	56	..	..
1931	21 May	„ „	24° F.	50	75	..	..	..

Manuring the Plants

The Problem and Previous Work.

It is obvious that the composition of the plant sap will be modified by the amount and kind of nutrient salts present in the soil. Since frost injury is, as we have already seen, closely bound up with the composition of the cell-sap, manuring or even natural differences in soil composition are quite likely to affect it.

The effect of manuring on frost damage is probably complex, and the small amount of work that has been done on it in the past indicates that this is so. Magistad and Truog (8), working with maize, found that the application of fertilizers increased osmotic pressure, which in turn lowered the freezing-point of the plant and made it hardier. On the other hand, McCool and Millar (10), working with clover, barley, &c., found that the strength of the soil solution

did not markedly affect the freezing-point depression of plants. Freckmann (3) holds that by the use of appropriate fertilizers the frost hardiness of agricultural crops on the moorland areas of Germany can be increased. Gorbing and von Hersberg (4) are of the opinion that a wrong proportion or quantity of salts in the soil increases frost damage. For instance, excessive nitrogen, or lack of phosphorus or potassium, may cause a failure to ripen shoots properly, and lead to subsequent frost injury.

Experimental Results.

Only a very small number of experiments, which are set out in Table XV, have been carried out on this factor. The oak and larches were potted in the winter of 1934–5, some in sand and some in soil with about a 50 per cent. admixture of spent hops. Half the plants were used in June 1935 and the remainder the following spring. In the first pair of experiments the manured plants were slightly more damaged, in the second those in sand, but in neither case was the difference very striking. These experiments are not sufficiently comprehensive to be used as a basis for any important deductions, but since the difference in manurial value of the two soils was very great, they suggest that manuring is not likely to be one of the more important factors modifying frost injury.

TABLE XV. *Effect of manuring*

				Damage percentage.		*Critical temperature.*	
Year.	*Date.*	*Species.*	*Frozen at.*	*Manured.*	*Sand.*	*Manured.*	*Sand.*
1936	13–16 May	Oak	19, 22, 24, 25, and 27° F.	37	15	22° F.	19° F.
1936	13–16 May	Jap. larch	19, 22, 24, 25, and 27° F.	30	20	25° F.	25° F.
1935	1–3 June	Oak	24, 25, and 27° F.	21	37	24° F.	25° F.
1935	1–3 June	Jap. larch	24, 25, and 27° F.	28	37	25° F.	25° F.

Handling Frozen Plants

It may sometimes happen in the nursery that plants are handled while the tops are still frozen. This is likely to cause a rather rapid thawing and possibly a rupture of the frozen tissues. Two experiments were therefore carried out to see what effect handling the plants while still frozen would have on frost injury. In the first, which was carried out from 8 to 11 January 1935, and in which birch, *Thuja*, and Norway spruce were used, the handled plants were slightly more injured, having a damage percentage of 53 as compared with 35 for the controls. In the second experiment carried out from 8 to 10 April of the same year, and in which birch and Sitka spruce were used, there was no effect at all. Further experiments are required, but it would appear that handling frozen plants is not as important a matter as might be expected.

V. DISCUSSION

On the basis of the experiments set out above we see that frost injury can be considerably modified by the preceding and accompanying climatic conditions. The temperature conditions before freezing, the rate of freezing and thawing, the duration of freezing, repetition of freezing and thawing, wind, and the presence of water on the plant all have a distinct effect on frost injury. In nature, of course, more than one of these factors may be acting at one time. In many cases one may increase injury, while another lessens it, and thus they counteract one another. It would be of interest to know, however, how great a difference in frost injury could be produced if all these factors were to exert their effect in the same direction. With this in view four experiments were carried out, which are set out in Table XVI. The 'well-treated' trees were kept in the open before freezing, and were frozen and thawed slowly; the 'badly-treated' trees were kept in a warm room for a few days before freezing, were sprayed before freezing, were quickly frozen and thawed, and were exposed to wind during freezing. It will be seen that very marked differences in frost injury occurred (Plate V, figs. 2 and 3). In the first experiment, for instance, the difference in the critical temperatures was more than 12° F., while only in the last experiment, where damage on both treatments was too severe, was there no really marked difference. It is very unlikely that in nature so many adverse or favourable factors would all act at the same time. But should such a thing occur frost injury could be very markedly affected indeed.

TABLE XVI. *Combination of factors*

Year.	*Date.*	*Species.*	*Frozen at.*	*Damage percentage.*		*Critical temperature*	
				WT.	*BT.*	*WT.*	*BT.*
1935	24 Jan.–2 Feb.	Scots pine	7, 10, 13, 14, 16, 19, and 21° F.	5	75	7° F. b	19° F
1935	22–27 Mar.	Scots pine	13, 15, 17, and 19° F.	22	70	15° F.	19° F. a
1934	14–17 Apr.	Sitka and Norway spruce	12, 14, 16, and 18° F.	11	64	14° F.	18° F. a
1935	29 Apr.–3 May	Korean larch	16, 18, 20, 23, and 24° F.	47	64	24° F. a	24° F. a

WT. = Well treated. BT. = Badly treated.

But apart from this rather exaggerated aspect, there is no doubt that in nature the degree of injury occurring during frost must often be modified by one or more of the factors under discussion, and when considering frost injury, or the possibility of frost injury, these factors cannot be neglected. Frost has too long been considered merely a matter of temperature. If allowance is made for the influence of other climatic factors on frost injury many puzzling anomalies could be wholely or partially explained. The main difficulty is that

full climatic data are seldom available. Even temperature records are often lacking, and fully to understand a frost one should know not only the minimum temperature, but have a complete temperature record before, during, and after the frost: in addition, one requires information on wind and rain, and possibly on humidity and soil conditions. There is no doubt that data of this type for a number of areas in which frost damage occurs with varying severity would be of great value in increasing our very incomplete knowledge of frost and its effect on plants. The importance of a proper understanding of site and climate in connexion with frost damage was emphasized by the authors (2) in their bulletin on the May frosts of 1935. Those frosts were accompanied by very varied climatic conditions, which in the absence of exact data defied analysis. There is no doubt that many of the unexplained effects of the frosts could have been elucidated if more had been known of local climate, and, on the lines of the experiments set out above, more known of the effect of climatic and edaphic conditions on frost injury. Far more experimental work both in the laboratory and in the field is required before these matters can be fully understood.

Our acknowledgements are due to the Forestry Commission, who provided the funds necessary to purchase the apparatus, without which this work would have been impossible, and who supplied the plants used. We also wish to acknowledge the help of Mr. F. H. Jones and Mr. B. Spital, who assisted with many of the experiments, and of Mr. L. A. Clinkard, who took the photographs.

SUMMARY

The underlying causes of frost injury are discussed and the conclusion arrived at that the mechanism of frost damage may be to some extent chemical, nutritional disturbance taking place, or toxic substances accumulating, during prolonged exposure to cold; it may be physico-chemical, the colloidal structure of the cell being damaged by too sudden alterations in the conditions under which it exists; or it may be physical, and depend on the rupture of the cell membranes by the mechanical action of ice. The effect of low temperature on the plant is undoubtedly a complex one, and more than one of these methods of injury is likely to be concerned with frost damage to trees.

On the basis of the authors' experiments it was found that:

1. Exposure of plants to warm temperatures before freezing increases damage, while cold temperatures lessen it.

2. Rapid freezing or thawing increases frost injury.

3. Damage is possible after 5 minutes' exposure to frost, or perhaps even less, provided the temperature is low enough, and will usually take place after 15 or 20 minutes' exposure below the critical temperature. An approximation to the maximum damage for any temperature is obtained after 1 hour's exposure, and often after a shorter time. After this degree of damage has been attained the increase of damage with time is slow, and often inappreciable.

4. Repeated freezing and thawing is usually more injurious than continued exposure to low temperature.

FIG. 1. European larch, frozen at 25° F. on 20 May 1933. Left to right, 1–3 sprayed before freezing, 4–6 not sprayed

FIG. 2. Norway and Sitka spruce, frozen at 12° F. on 14 April 1935. Left to right, 1–4 badly treated, 5–8 well treated

FIG. 3. Scots pine, frozen 24 and 27 January 1935. Left to right, 1–4 frozen at 8° F., well treated, 5–8 frozen at 16° F., badly treated, 9–12 frozen at 16° F., well treated

PLATE V

5. The time of day at which frosts occur has no effect on the amount of injury.

6. Wind increases damage, but variations in the humidity of the air have practically no effect.

7. The amount of moisture in the soil, and the plants ability to absorb this moisture, have little or no effect on frost injury.

8. It is not easy to cause damage to plants with roots in frozen soil by excessive transpiration.

9. Frost injury is increased by the presence of moisture on the plant just before or during freezing.

10. Manuring has little effect on frost injury.

11. Handling frozen plants has little effect on frost injury.

12. And finally, very large differences in injury can be caused if several of the factors mentioned above all exert their influence in the same direction.

(*concluded*)

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THE WATERMARK DISEASE IN THE WHITE WILLOW

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INTRODUCTION.

IN his account of the first investigation of the watermark disease of the cricket-bat willow, Day (2) mentions that the white willow is also sometimes attacked in Essex, and a similar disease in these trees was described some years later by Lindeijer (4) as of common occurrence in Holland. Largely owing to the fact that Miss Lindeijer ascribed the disease to a different organism closely associated with the weevil, *Cryptorrhynchus lapathi* L., a further investigation was made in this country (3). This showed that the disease of the cricket-bat willow, *Salix caerulea* Sm., in Essex was due to *Bacterium Salicis* Day, and that a similar organism was present in the white willow of Cambridgeshire. It was further pointed out that in Essex *S. caerulea* is the willow most commonly found and that *S. alba* is rare, whereas in Cambridgeshire the reverse is true. The common tree willows of the fens are *S. alba* and hybrids between this and *S. fragilis*, known as × *S. viridis* (1), many of which are very like *S. alba*. As *B. Salicis* had been isolated from *S. caerulea* in Essex and from *S. alba* in Cambridgeshire, it was considered of importance to prospective bat-willow growers to find out whether or no the organism of the white willow would infect the cricket-bat willow, and, if so, the extent and distribution of the disease in the former. It was also considered worth while to find out if the organism of the cricket-bat willow would infect the white willow.

The present paper gives an account of our investigations of these problems and records the results. Healthy young trees of *S. caerulea* and *S. alba* have been inoculated with the appropriate organism and a partial survey of the fens has provided the position of the diseased areas marked on the map on p. 106.

EXPERIMENTAL.

Trees specially planted at Cambridge were inoculated in the same way as that described in the account of the previous investigation (3).

I. *B. Salicis* isolated from the white willow was inoculated into the bat willow.

On 20 October 1936 four trees were inoculated; two were 2 years old, one was 3 years old, and the fourth 4 years old. External symptoms of the disease in the form of withered and reddish-brown leaves, known as the 'red-leaf' stage in Essex, were first observed in one of the youngest trees on 29 May 1937. By 8 June several shoots were showing 'red-leaf' and when cut off were found to be watermarked. From the exuding sap of one such shoot *B. Salicis* was recovered in the manner already described (3). The inoculated branch of

the other youngest tree broke off in a wind a few weeks after inoculation and no 'red-leaf' developed in 1937, but on cutting into the main stem in August 1937 extensive watermark was present in the 1936 ring of wood. The two older trees showed no sign of infection in 1937.

The results of these inoculations show that *B. Salicis* from the white willow can produce watermark in the bat willow.

II. *B. Salicis* isolated from the bat willow inoculated into the white willow.

The *S. alba* sets for this experiment were some of those kindly provided by Mr. H. P. Hutchinson of the Long Ashton Experiment Station, Bristol, and were of two kinds, one exhibiting a distinctly pendulous habit. After planting in January 1936 two of each kind were inoculated on 8 August. One of each sort showed no sign of infection during the following season, and on cutting off several of the shoots in August 1937 no watermark could be detected. The two other trees (one of each kind) were severely infected in 1937. In one of them 'red-leaf' was visible on 18 May, and the pendulous variety developed this symptom on 24 May. The wood of both was much watermarked and from one of them *B. Salicis* was recovered.

The results of these inoculations show that *B. Salicis* from the bat willow can produce watermark in the white willow. The general conclusion from both sets of inoculation experiments is that the diseases of the two willows are the same and are due to the same organism.

SURVEY.

During the winter of 1936–7 trees of *S. alba* were frequently noticed in the Cambridge fens with considerable die-back, and it was thought that they might be watermarked. As it was impracticable to search for the disease in winter when there are no leaves and the wood contains but little sap, a survey was postponed until June and July, when it was found possible to visit a number of localities in the area. Watermarked trees are very conspicuous in summer when the 'red-leaf' symptom develops.

The symptoms of the disease in the cricket-bat willow are the dying-back of branches, patches of reddened leaves, the watermark in the wood, and an exudate flowing from a cut surface of such wood or from wounds. The symptoms of the disease in the white willow appear to be in no way different from those in the cricket-bat willow. Trees of *S. alba* and × *S. viridis* showing the 'red-leaf' symptom and watermarked wood were found at the following places: 1. Wretton,* Norfolk; 2. Stoke Ferry,* Norfolk; 3. Northwold, Norfolk; 4. Methwold, Norfolk; 5. Lakenheath, Suffolk; 6. Eriswell, Suffolk; 7. Mildenhall,* Suffolk; 8. Barton Mills, Suffolk; 9. Earith,* Cambs.; 10. Haddenham, Cambs.; 11. Wilburton,* Cambs.; 12. Twenty Pence Bridge, Cambs.; 13. Chittering, Cambs.; 14. Denny Abbey, Cambs.; 15. Waterbeach,* Cambs.; 16. Long Stanton, Cambs.; 17. Fen Stanton, Cambs.; 18. Hemingford Grey, Cambs.; 19. Grantchester, Cambs.; 20. Sawston, Cambs.; 21. Whittlesford,* Cambs.; 22. Ickleton, Cambs.; 23. Great Chesterford,* Essex; 24. Little Chesterford, Essex; 25. Littlebury, Essex.

Fig. 1 indicates where *S. alba* was found with symptoms of the disease. From this it will be seen that the disease in the white willow is widespread and is

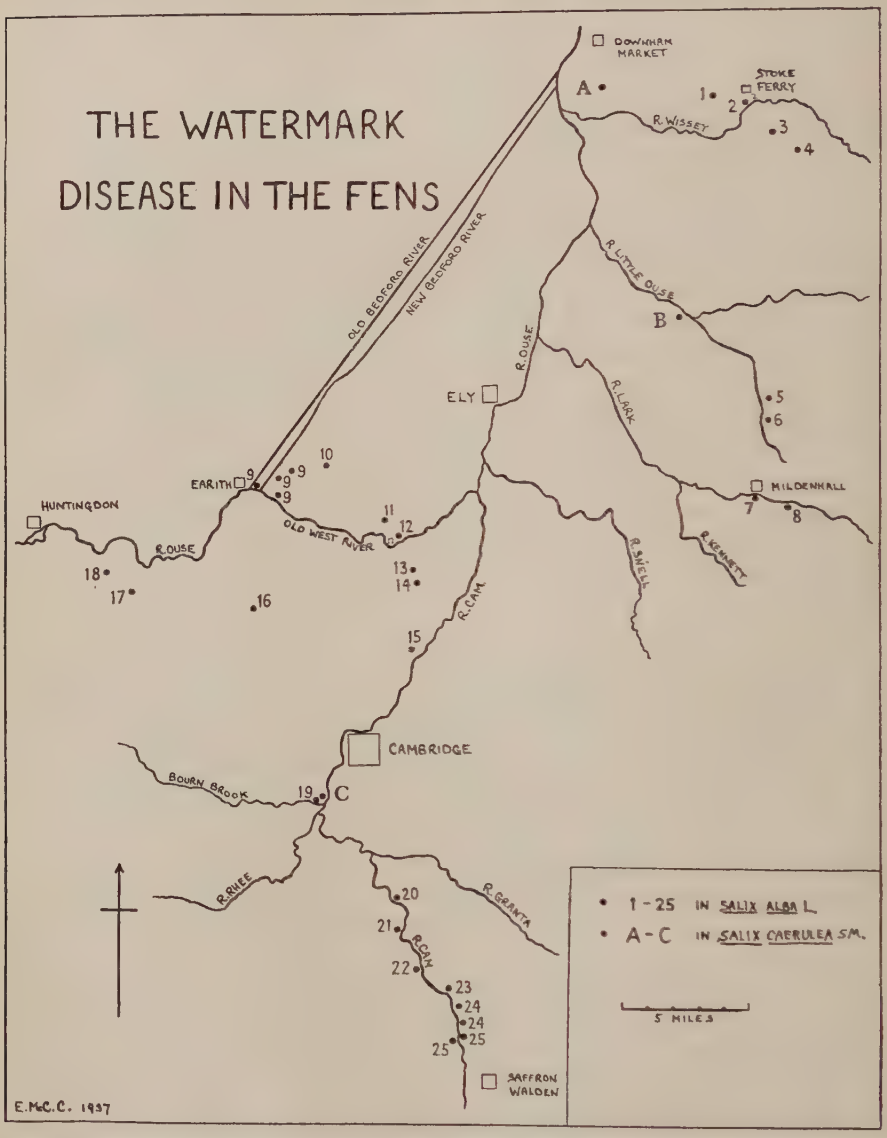

Fig. 1. Distribution of watermark in the white willow along the river Ouse and its tributaries. The numbers and letters are referred to in the text.

common along the tributaries of the river Ouse. A further survey would probably disclose more localities of the disease because the upper reaches of most of the rivers have not been examined. This applies particularly to the Wissey, Kennett, and Snell. In a number of places the disease appeared to be of long

standing, the appearance of the trees being comparable with that of the bat willow on the river Chelmer below Chelmsford, where the disease is known to have been present for many years.

At each place, specimens of the wood were cut and examined in the field and showed the watermark characteristic of the disease. A copious exudate frequently flowed from the cut surfaces of the stained wood. Specimen branches with the watermark stain were taken from a number of localities for examination at Cambridge, the exposed ends being protected by a layer of vaseline applied immediately after cutting. *B. Salicis* was successfully isolated from material collected from the places marked * in the above list.

In the following three places bat willows were found watermarked, but in none did the disease appear to be of long standing. These are also indicated in Fig. 1. A, Ryston, Norfolk; B, Shippea Hill, Suffolk; C, Grantchester, Cambs. At Grantchester (No. 19) old trees of the white willow, both unmutilated and pollarded, had considerable die-back and 'red-leaf', giving the impression of an infection of some years standing. Bat willows adjacent to the diseased white willows were watermarked, but apparently had only become infected comparatively recently, which strongly suggests that the disease had spread from *S. alba* to *S. caerulea*. The watermarked bat willows at Ryston and Shippea Hill had also probably become infected from diseased white willows which are in the neighbourhood. The danger of planting the bat willow in areas where the watermark disease is already present in the existing white willow cannot be over-emphasized.

The survey, although far from complete, has shown that not only is there much watermark of long standing among the white willows of the river Ouse and its tributaries, but also that the same disease is present in the uncommon bat willow in a few places in this area. Furthermore, the bat willows referred to have but recently acquired the disease, probably from the white willow. Little, if any, attention has been paid so far to the disease of either willow in the fens, partly because of the very small economic value of the white willow. It seems probable that watermark is indigenous in *S. alba* in the fens and has not been derived from *S. caerulea* in Essex, as there is no obvious connexion between the disease of one kind of willow in the fens and of the other kind in Essex.

SUMMARY.

The white willow (*Salix alba* L. and × *S. viridis*) is subject to a watermark disease precisely similar to that of the cricket-bat willow, *S. caerulea* Sm., as cross-inoculation experiments show that *Bacterium Salicis* Day is the cause of the watermark in both willows. Whereas the commonest willows along the Essex rivers are *S. caerulea*, those of the Cambridgeshire streams are *S. alba* and its hybrids, many of which have long been diseased over a wide area. Bat willows recently planted in a few places have contracted the disease within the last few years, probably from adjacent white willows, the disease in which is thought to be indigenous in the area and has not been derived from Essex.

One of us (E. McC. C.) wishes to express his indebtedness to H.M. Forestry Commission for a grant which made this survey possible.

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THE DYING OF LARCH: A NOTE ON PROFESSOR E. MÜNCH'S MONOGRAPH 'DAS LÄRCHENSTERBEN'[1]

BY W. R. DAY

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THIS very long paper of just over one hundred pages is a monograph dealing in considerable detail with the cause of the die-back of larch which has been so frequent in many of the stands established in Germany, over a period of more than 150 years, and which has occurred also in this country. In Germany as in Britain, the European larch has always attracted foresters on account of its high economic value and good rate of growth. There, as here, it has been planted extensively in many and various situations and with a great variety of results. Some stands have succeeded well, but many have proved more or less a failure, and the species has tended to come into, or go out of, fashion largely according as its success or failure happens to be uppermost in the mind of foresters at any particular time. In Britain its success has been so great, and its failure so tantalizing, puzzling, and disappointing, that any attempt to explain satisfactorily the reasons why this potentially valuable species has so frequently failed must be of importance to British foresters. The great value of this paper is that it gives satisfactory, and, one must believe, in the main fundamentally correct reasons, for the die-back and canker of larch which has puzzled foresters and pathologists for so many decades. It is not, nor does it pretend to be, a treatise dealing in detail with the habitats and general biological requirements of the various races of European larch, but it deals with matters which are fundamentally necessary to the writing of such a treatise.

The author first demonstrates that even in the eighteenth century the 'larch disease' was of importance, and that thereafter it repeatedly occurred according as the species was more or less extensively planted. Even widespread and serious losses owing to disease failed to impress foresters sufficiently to prevent further stands being established, so that to-day young plantations are growing up, some of which may be expected to become diseased in due course.

The general symptoms of the disease are described in some detail and with reference to the observations recorded in past literature, as well as to the author's own experience. The lower branches are usually first affected, and the disease progresses upwards so that the crown becomes increasingly smaller and irregular. The disease usually develops quite suddenly, and is not necessarily accompanied by any formation of cankers. Nevertheless many small cankers commonly occur on the partly injured twigs in the zone immediately above those which have been killed. The dead branches, and the dead pieces

[1] *Forstwissenschaftliches Centralblatt*, lviii, 1936, pp. 469–94, 537–62, 581–90, and 641–71.

of those partly alive, quickly become covered with lichens, this being a feature of the disease. Stands are most commonly affected when in the pole stage, say, 20–30 years old. The die-back continues at intervals until frequently only a bush of green crown is left at the top of the tree or even that dies. Many epicormic shoots commonly develop, and these give badly affected trees a characteristic appearance. The continual die-back weakens the trees, which frequently die. A further characteristic is the development of rough bark on stems which would normally be smooth. This is caused by the dying of outer portions of bark: usually the cambium is not killed. The fructifications of the larch-canker fungus *Dasyscypha willkomii* (Hart.) Rehm. (= *D. calycina* (Schum.) Fuckel.) commonly occur on the dead parts.

There have been many explanations of the origin of the disease. Many of the earlier observers considered that its cause was to be found in repeated frosts or cold mists and pointed to the frequency with which the disease occurred in frosty localities, which usually are places where cold mists arise. In Britain, evidence was published to this effect in the *Journal of the Royal Scottish Arboricultural Society* (1905), and Marshall Ward (8) also drew attention to it. Some time before this, however, Willkomm and R. Hartig had more or less identified the die-back disease with canker and associated both with the fungus *Dasyscypha willkomii*. So much clear evidence of the association of plant diseases with fungus parasites was produced in the latter part of the nineteenth century that the earlier views of the possible non-parasitic origin of the disease were almost entirely overlooked or regarded as worthless. Only a few observers, such as Marshall Ward, and particularly Sorauer in his *Handbuch der Pflanzenkrankheiten*, persisted in drawing attention to the importance of frost. The fungus thus came to be considered, almost universally, as the actual cause of the disease. The fact that trees not uncommonly recover from canker, and sometimes from die-back, led many observers to consider that predisposing factors were necessary to make the trees susceptible to the larch-canker fungus which they regarded as the immediate cause of the disease. These factors were commonly found in wrong silvicultural treatment, such as wrong mixture of species, or lack of mixture, or failure to thin sufficiently; and a wrong habitat marked by unsuitable soil conditions, or rainfall, or degree of warmth, or intensity of light during the growing season. Others even claimed that the climate had altered, or that the mother seed trees had degenerated. In some countries, however, e.g. Sweden and Denmark, the problem was approached from the racial standpoint and investigation showed that certain races of larch were superior to others in certain places, thus giving an indication of one of the fundamental causes of the disease, viz. unsuitable provenance of seed in cultivated stands.

Münch points out that actually the die-back occurs on sites of all types as judged by quality of growth, and in well-treated and ill-treated stands, and that if a sufficiently wide survey is made it thus becomes plain that reference to treatment and habitat alone (overlooking frost) provides no satisfactory explanation of its occurrence.

One now comes to the actual proof of the cause of the disease. It may be pointed out that while a number of observers had claimed to have reproduced larch canker by the inoculation of trees with *D. willkommii*, no one, until recently, had ever claimed to have demonstrated the cause of die-back. Sorauer had, however, shown that small frost cankers, similar to those which occur naturally, could be produced by experiment. In 1931 (2), however, the present writer pointed out that in small larch cankers abundant anatomical evidence could be found which demonstrated that frost was the cause of their development, and in 1934 (3) he, together with T. R. Peace, published evidence obtained from freezing experiments, which showed that experimental demonstrations could easily be made that frosts such as commonly occurred could cause the die-back and cankering of small larch. The anatomical evidence provided by the experimental material was discussed and compared with that obtained from natural cankers, whether or not these were associated with die-back or canker, and shown to be essentially the same. Münch has carried out similar experiments which have confirmed the above, and it may be taken as proved that in the first instance both die-back and canker are caused by frost.

The role of the fungus in larch canker and die-back still remained to be demonstrated, however. Day and Peace concluded that in any case it was secondary in importance to that of frost, and that, at least so far as the small cankers they had worked on were concerned, it appeared to merely fill the role of a saprophyte.

This is a point at which this paper becomes of great interest. Dr. Langner (5), working at Professor Münch's Institute at Munich, re-examined the whole question of canker development and came to the conclusion that the fungus played a secondary but quite definite and necessary role in this. Cankers begin as frost injuries which almost invariably centre round a shoot or small branch. The frosted tissues become colonized by the fungus which lives in them as a saprophyte and never invades the living tissues. What happens, according to Langner, is that the fungus lives in the dead bark immediately adjacent to the living edges of the wound, and so affects the tissue of these that it becomes susceptible to injury by winter frost. The physiological explanation given for this is that, under the influences of the fungus, tannins are accumulated in the cells at the expense of sugars, with the result that the freezing-point is raised sufficiently for winter frost to be able to cause death. An interesting proviso comes in here. In a climate of a continental type with an uninterruptedly cold winter, the temperature is continuously too low for the fungus to grow. Accordingly, it cannot affect the living tissues, and no death from frost, and, therefore, no canker development occurs. In a climate of an oceanic type where mild periods commonly alternate with cold ones, this is not true. Fungal development takes place during the mild periods with the result that the edges of the canker are susceptible to frost injury when a cold period comes again. The role of the fungus in canker development is, thus, to make tissues susceptible to frost injury: it has no real direct parasitic action but feeds entirely as a saprophyte.

This theory will doubtless be disputed: e.g. Hahn and Ayers (4) call the larch-canker fungus an obligate parasite definitely and compulsorily associated with canker development. This is not a view which the present writer personally favours. Subject to suitable confirmation, there seems to be no reason for not accepting Langner's general conclusions as correct. Work in other directions, viz. that of Birch (1) on the *Phomopsis* disease of *Pinus insignis* in New Zealand, has demonstrated that there may be a close and important co-operation, in the causation of disease, between frost and fungus. So far as Britain is concerned confirmation is needed that winter frosts are those which cause the edges of the canker to die-back. Our work has shown so close a connexion between the development of small cankers of four or five years of age and frosts which occur during the period of active metabolism that there seems to be no doubt that in Britain at least frosts during this period, that is late winter, spring, and autumn frosts, commonly initiate and continue canker development.

According to the above theory there is an obvious relationship between the die-back of larch and canker development. Both begin as frost injury and both may obviously be continued by the combined action of frost and fungus. To the writer it seems that Münch and his school bring in the fungus too compulsorily into the continued growth of cankers. One may admit freely that its role is as Langner has described, and yet find it difficult to escape the conclusion that if frost is able to initiate canker development without the help of the fungus it is also able to continue it. This would, for example, make easy the explanation of the frequent irregular development of cankers, which may heal over in one part and yet die-back in others, for frost acting from year to year is notoriously irregular in its destructive action on potentially susceptible tissues. The insistence on the role of the fungus also makes the healing of cankers somewhat difficult to explain, particularly if winter frosts are to be accounted as the principal factor in continued canker development. These criticisms are not made to belittle the valuable work that has been done, but to suggest that it should be continued until a full and completely satisfactory explanation has been obtained of this problem.

One may also briefly refer to Münch's interesting remarks on the lichen development which is so characteristic of the dead parts of trees affected by the disease. Münch suggests that the probable explanation of the reason why lichens develop luxuriously on bark killed by frost, and yet may be growing but poorly or not at all on adjacent normal rough bark, is that they profit by the high content of food substances within the former; in normal bark, on the other hand, food substances are largely withdrawn from the cells before the cork cambium isolates the bark tissues. This is an interesting matter on which also further observations might well be made, for he suggests that in the case of larch at least it is the food content of the bark rather than the humidity of the air which is the determining factor in the luxuriance of lichen growth.

Lichen development is also of interest in that it frequently helps to indicate

the rate of progress of the ascending die-back of the crown by the relative luxuriance of its development on different zones of dead branches. The ascending character of the die-back is explained by the fact that the upper branches of a tree are hardier to frost, owing to a higher concentration of cell-sap constituents, than are the lower ones. The fact that temperatures near to the ground tend to be somewhat lower than those higher up is held to be of minor importance.

The fundamental importance of the work so far reviewed is that it confirms the theory that larch canker, and also the common die-back of larch usually referred to as larch disease, are caused by, or at least have their development necessarily initiated by, frost. The importance of this conclusion for the cultivation of European larch is obvious. It provides, however, not the end, but the beginning of the solution of the problems which confront those who would cultivate larch whether within, or outside, the range of its natural distribution.

As the work of Schotte (7) in Sweden, and Oppermann (6) in Denmark, shows, foresters have appreciated for some time past the importance of the provenience of seed in the cultivation of larch, as of other trees. Münch has taken this point up and has examined the question of larch disease from the racial standpoint. He finds that in Germany diseased stands appear without exception to have been raised from seed of Tirolese origin, whereas healthy stands have been raised in the majority of cases from seed of the Sudeten race of larch, the native habitat of which is in the mountains on the borders of Silesia and Czechoslovakia. He considers the Sudeten race, for all practical purposes, to be immune to larch disease when cultivated in most parts of Germany. This high immunity is put down to the similarity in climate between the natural habitat of the Sudeten larch and the rest of Germany. This climate is not so markedly continental as that of the area to which Tirolese larch is indigenous; it has a longer growing season, a longer season in which early and late frosts may occur, and is less protected from westerly and particularly from cold northerly winds. The result of this is that in Germany the Sudetan larch has a growing season which fits better into the seasonal cycle than does that of Tirolese larch, and also it is a somewhat frost-hardier tree. The Tirolese larch itself is in reality composed of a number of climatically dissimilar races and this is true of the alpine larch as a whole. This is due mainly to the great range of climate to be found between the higher and lower levels at which larch grows in the Alps. The Sudeten larch, however, comes from a habitat much more uniform climatically and thus is much more uniform racially, the differences within it not being very marked. The solution of the problem of larch disease is thus, according to Münch, to be found in the selection of a race suited to the climate of the locality concerned. For Germany this race is to be found in the Sudeten larch; other countries must work out for themselves the solution of this aspect of the problem.

Münch discusses, in order to dismiss, other theories than the one he propounds as to the cause of the common failure of cultivated larch stands. Tschermak's

theory that a wide variation in temperature between summer and winter is a necessity for the good growth of larch is shown not to be tenable. This really was equivalent to saying that larch would only grow well in a climate of a continental type; but taking the species as a whole, this is obviously not true. Similarly he dismisses the evaporation and humidity theory. This stated that a high rate of transpiration was a necessity to larch; that because of this it needed to grow in places where there was usually a high rate of evaporation but also where the soil provided a good water-supply. It can be shown that larch grows under a wide variety of conditions as regards soil water-supply and also that it often grows healthily and to a very great size in narrow enclosed humid alpine valleys. The only stipulation is that these valleys shall be frost free, except, of course, during winter.

It seems to the writer that Münch dismisses too lightly the viewpoint of those who associated susceptibility to disease with wrong treatment and wrong choice of habitat (excluding the factor of frost, the importance of which has been so commonly overlooked). The immediate cause of the common die-back and canker of European larch is, of course, frost, whether with or without the association of the fungus. But the healthy thriving of larch is a much wider matter than mere avoidance of die-back or canker, important and highly significant as that is. In Britain, at least, the stress of treatment and habitat was typically made by the practising forester. The widespread dying-back of larch has never been his main trouble, and one may travel far in Britain without seeing a really good example of it. Again, larch canker, although extremely common and widespread, only causes great trouble in restricted localities. It is, however, at least equally common for European larch to establish itself with difficulty, to grow slowly during the first years, and eventually to make a rather open plantation. This unsatisfactory early growth may or may not be associated with die-back and canker, but it certainly is related to choice of habitat and the treatment which this and the crop has received.

Again, while disease caused by frost may effect larch which have reached the pole stage, it is quite common here to find much smaller trees which have become cankered or have died-back owing to frost injury, and then the lower part of the tree is not necessarily the most affected. In Britain, in fact, this disease of larch may develop at almost any age, although large trees are not usually affected. There is, also, an undoubted relationship between the degree to which trees thrive, and their corresponding vigour of growth, and the development of this disease. There are, thus, many places in Britain in which frost injury is likely to cause serious disease only while trees are small; once they have reached a height of from 10 to 15 feet they are out of serious danger. In such cases the vigour of growth while young is of great importance, for it largely determines the length of time during which the trees will be exposed to serious danger. Obviously the larch shoot and leaf-mining moths and other insect pests may be of great importance here as well as soil conditions and general treatment. Similarly, instances have occurred in which it has seemed beyond all doubt that variations in soil conditions have greatly affected the

ultimate effect of frost injury on trees similarly situated and of similar age and size.

While, thus, it is of fundamental importance to recognize the true cause of the development of a die-back or canker, it is also of equal importance to recognize that other conditions affect the growth and health of the tree and that these may have a considerable influence on the tendency of trees to succumb to, or to recover from, injury from frost whether or not assisted by fungus influence. The comparative success of pathologists in providing an explanation of the cause of certain larch diseases, and in suggesting means by which they may be avoided, still does not relieve the silviculturalist from the necessity of determining the general conditions under which, at any particular stage of its existence, a healthy larch stand may be obtained.

The riddle of the larch, to use an expression of common occurrence in German literature, is thus slowly in process of being solved. It would be idle to say that the requirements and character of the species are fully understood and can now be fully and clearly stated without fear of contradiction; but a further and important advance has been made and confirmed. British foresters should not rely on Sudeten larch being especially suited to our conditions. This is in process of being proved experimentally. At least we know that the Scottish larch, if planted in suitable localities, is well worthy of propagation in this country and it would seem best to keep to our own race as far as possible until a better one is proved to exist. It seems to be certain that it will always be necessary carefully to avoid localities in which serious late and early frosts occur, if serious die-back or canker of larch is to be avoided. Münch's paper gives the impression that he considers that such careful selection of habitat will not be necessary in Germany provided Sudeten larch is used. This may be true to some extent, but it is extremely unlikely that in Britain any race of European larch will prove to be so hardy that it may be planted in frosty localities without grave risk of serious disease developing. The frost risk naturally varies greatly from place to place, and if one only knew how well any particular race of larch fitted in to the types of climatic habitat available in Britain, it would be possible to estimate fairly accurately which were reasonably suited to it. The solution to the larch problem is to be found, in fact, simply in fitting race of tree to habitat. The experimental plantings of various larch races in this and other countries show that this has been realized in part for some time past, but until the role of frost in larch disease was brought out it was not realized, so fully as might be, how important a matter this is. Nevertheless, the forester is to be warned against thinking that all the troubles of European larch are caused by frost, for even when frost injury is avoided there will still be enough matter left to give him food for thought, and, upon occasion, anxiety.

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THE MYCORRHIZAL HABIT IN *PINUS*: A COMMENT

BY M. C. RAYNER

IT is to be hoped that the publication of Hatch's paper on mycotrophy in pines, reviewed in pp. 128–32 of this number of *Forestry* (2), does not foreshadow a revival of old and barren controversies respecting the physiological role of the fungus partners in mycorrhizal plants. Hatch's contention that the 'mineral salt' theory of nutrition, put forward by Stahl in 1900 in his classical paper 'Der Sinn der Mycorrhizenbildung', is 'by far the most accurate picture of mycotrophy in pines that has yet appeared' is supported by a wealth of argument derived both from the literature and from his own experimental studies. If there yet exists any serious student of the subject with a background of knowledge derived from experiment—in particular from field experiment—who doubts that correct mycorrhizal equipment in pines or other trees increases root efficiency in respect to absorption of nutrients, the evidence so ably marshalled by Hatch should go far to remove their disbelief.

Some of the evidence derived from Hatch's own researches is new and valuable, especially that demonstrating the increase in absorbing surface brought about by mycorrhiza-formation and that relating to the mechanism by which absorption of nutrients is effectively increased by fungus association. His own theoretical interpretation of the manner in which the mycotrophic habit actually operates in the nutrition of pines is stimulating and provocative. The argument presented against the acceptance of what is commonly known in relation with mycotrophy as 'the nitrogen theory' is less convincing. In the form originally put forward by Frank in 1894 it constituted a claim for the utilization of ammonium salts and organic compounds of nitrogen as sources of nitrogen by forest trees. Frank believed that the existence of the appropriate fungi—and hence the formation of mycorrhizas by trees—was conditioned by the presence in woodland soils of humus derived from fallen leaves and other organic residues of the trees growing in such soils. His conclusions as to the relations of the root fungi of trees with the nutrition of their hosts were based mainly upon the structure of ectotrophic mycorrhizas, and led him to conclude that the roots of conifers, like those of members of Cupuliferae, depend for their proper nutrition upon the presence of their appropriate root fungi. Forest trees and other plants growing in soils deficient in nitrates must obtain their supplies of nitrogen either as ammonium salts or as organic compounds of this element. This they were enabled to do through the agency of the mycelium associated with the mycorrhizas, which thus acted as 'foster-mothers' to the trees. It was pointed out that potassium and other essential elements were locked up in the organic residues of humus and that these also might be made available by the metabolic activities of the fungi.

In spite of the arguments advanced against the 'nitrogen theory' of myco-

trophy, Hatch's own position in the matter is not quite clear. Is it to be inferred that the acquisition of '86 per cent. more nitrogen' by the mycorrhizal than by the non-mycorrhizal seedlings in his prairie soil experiment is related solely with the more efficient collection of nitrates? No information whatever is given respecting either the organic content or the nutrient capacity of this soil, and no opinion is expressed by the author as to the origin of the increased nitrogen content. The claim that peptone and nucleic acid can be absorbed directly by the roots of pine seedlings is not discussed from this point of view.

Melin, the most distinguished modern exponent of the application of this theory in a modified form to the problem of mycotrophy in trees, reached the conclusion 'dass die Mykorrhizen für die Pflänzchen und Bäume auf Rohhumusböden und verwandten Bodentypen eine vitale Bedeutung besitzen' (3, p. 119). The results of experiments to test the Stahl hypothesis in respect to inorganic salts were on the whole in agreement with the view there stated, although the benefit derived by the trees by increased absorption of other elements was regarded by Melin as quite secondary to that associated with nitrogen assimilation. His verdict in respect to this in relation to the raw humus soils under observation in Sweden was as follows: 'Während jedoch Stahl meint, dass die Mykorrhizapilze anorganische Salze an die Wurzeln vermitteln, liegt die Bedeutung der Mykorrhizen nach meiner Ansicht in erster Linie darin, dass sie auf Böden vom Rohhumustypus den für den höheren Symbionten nötigen Stickstoff leichter assimilieren können als die Wurzeln allein. . . . Es ist zwar möglich, dass ausserdem auch gewisse andere Nährstoffe in der Humusdecke, wie Kalium- und Phosphorsalze, durch die Mykorrhizen leichter aufgenommen werden als durch die Wurzeln allein; da aber diese Salze auch in dem darunterlegenden Mineralboden zu finden sind, dürften sie durch nicht verpilzte Wurzeln auch von hier aufgenommen werden können' (3, p. 106).

The view that the two theories of nutrition identified with the names of Frank and Stahl respectively were to be regarded as mutually exclusive had not presented itself to the writer. It was felt that the value they presented as a physiological background for modern experimental work lay rather in their complementary character, the relative importance and applicability of one or other theory depending greatly on the nature of the soil conditions. The views of the writer were, and still are, in general agreement with those expressed by Melin, with sufficient added elasticity in the direction of the Stahl hypothesis to cover all types of soil in which mycorrhizas are freely formed. In respect to this matter, exception is taken to Hatch's unwarranted statement that certain experimental researches of the writer relating to unsatisfactory growth of pines on a poor heath soil were 'planned from the viewpoint of the nitrogen theory' (2, pp. 311, 312). This is a quite inaccurate statement of the facts. In the first instance, these researches were planned to provide adequate experimental proof of the *critical importance of mycorrhizas normal for the species in the nutrition of young trees*, and 'following such proof, in cases where

unsatisfactory growth is associated with absence of mycorrhizas, or with the appearance of fungus-roots of aberrant structure, to determine whether the condition of the trees in such respect was due to (1) absence of mycorrhiza-formers appropriate to the species, or (2) the existence of soil conditions inimical to the formation of mycorrhizas of a type beneficial to the trees' (6, p. 105). The future of profitable research on tree mycorrhizas with laboratory exploration of the basic physiological problems involved was believed to be 'bound up with the answers to these questions'. The statement that seedlings already present on the area gave the impression 'of chronic starvation especially in respect to nitrogenous constituents' was descriptive and was not intended in any sense to exclude the probability of deficient supplies of other essential nutrients in a soil known to be deficient in all such.

The researches in question relate to a poor heath soil in Dorset where sowings of several species of pine had given poor and unsatisfactory results. Preliminary experiments in soil inoculation with small amounts of humus containing active mycorrhizal material from native stands of Scots pine and Corsican pine had given striking results. The experiments were of similar character—although rather more refined in scope and technique—to those carried out in forestry experiments in various parts of the world by other observers and reviewed in detail by Hatch (2, p. 62). They gave similar results and served to strengthen the already strong circumstantial evidence for the belief that there exists a direct causal relation between normal mycorrhizal development and healthy growth. The results of the more critical experiments in which pure-culture inoculation with specific mycorrhiza-formers replaced that with humus are included in a forthcoming paper.

The earlier stages of the work had led to the use of certain organic composts. In a paper to which reference is made by Hatch (2, p. 63), the deductions leading to the use of these composts and the hypothesis of the soil condition that provoked them are fully discussed, and the general results of the experiments indicated. These results included not only the 'enormously stimulated growth of seedlings . . .' mentioned by Hatch, but also remarkable changes and variation in mycorrhizal response. The section dealing with them ends thus: 'As it is proposed to deal fully with the preparation, constitution, and effects of these composts in a separate communication, it suffices . . .' That promise was fulfilled in a second paper of the series published in this journal in 1936 (7), and therefore at Hatch's disposal for almost a year before the publication of his own monograph. No reference whatever is made to this second paper in the text, although it is cited in the bibliography. That he should find these experiments of no particular interest for the development of his argument is unimportant. That he should dismiss them with the comment that 'comparative data in the growth of seedlings in soils with and without organic composts are not given' (2, p. 63), and suppress reference to the subsequent communication that provided such data, cannot be allowed to pass without protest. To a reviewer, such an oversight inevitably suggests the need for close scrutiny of Hatch's critical evaluation of the literature relating

to his own subject. All the collected observations on mycorrhizal activity and structure derived from these compost experiments, with the conclusions reached in respect to the distribution and activity of certain mycorrhiza-formers and other soil fungi in the experimental area, will be published in the third paper of the series now in preparation. With these will be included the root diagnoses and comparative growth-records from control plots and those inoculated with pure cultures of known mycorrhiza-formers. Publication of this section of the Dorset work has been delayed in order to test the permanence of reactions exhibited by young seedlings. In the case of trees, some doubt was felt as to the propriety of basing final deductions as to behaviour only on the reactions shown by seedlings a few months old. Publication of this paper is mentioned because many of the observations and conclusions are in agreement with those described by Hatch (2) and by Mitchell (4) (see Review, p. 128, of this journal); e.g. those relating to the effects of increased nutrient supply on root and mycorrhizal development. There is, however, conclusive evidence that very marked changes in these respects, with correspondingly large effects on growth and vigour of the seedlings, may be associated directly with variation in other soil factors. It may be added that certain of the experimental results have a direct bearing on the vexed problem of nitrogen assimilation in pines, and can be applied directly to the solution of this problem.

In view of a statement by Hatch (2, p. 104) associating the writer's name with the views of Burges (1) and with the 'assumption(s)' that 'mycorrhizae benefit trees merely by converting non-available soil materials into readily available nutrients' quotation may be perhaps permitted: 'It is probable that many evolutionary stages, marked by greater or less specialization of the symbiotic relations, are represented among trees. In the genus *Pinus*, I have reached the view that the association is highly specialized and depends upon soil conditions for maintenance of the normal equilibrium. Any disturbance of these conditions may result in changes that react adversely or even disastrously upon the health and vigour of the host.' Also: 'Under stabilized conditions the association of fungus and host in pines is a balanced one, closely correlated with local conditions of soil and often operating within very narrow limits.' Were it called for it would be easy to multiply such quotations from my published work. My own conclusions for the genus *Pinus* were summarized in the paper cited. In respect to the incidence of mycorrhizal development in the short-root system and the mutualistic character of the association they are in complete agreement with those now expressed by Hatch (Rayner (5), pp. 311, 312).

Inasmuch as certain statements made in respect to papers published by me in this journal are inaccurate in fact and misleading in implication, I am greatly indebted to the Editor for this opportunity to correct them. This note makes it possible at the same time to restate my present views respecting the mycorrhizal habit in pines and other conifers, and make clear the direction taken by my own researches.

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THE CLASSIFICATION OF CONIFERAE, II

BY J. BURTT DAVY

THE arrangement followed in the previous article (vol. xi, No. 1, pp. 53–6) was adopted for convenience in keying out the Families and does not quite follow that of Pilger (in Engler and Prantl, *Die Natürlichen Pflanzenfamilien*, Aufl. 2, Bd. 13, pp. 121–403). Pilger does not recognize the two Orders (*Reihe*) in the Class Coniferae, as used by other authors; he treats all the Families as belonging to one Order, and places the *Araucariaceae* between *Podocarpaceae* and *Cephalotaxaceae*, the *Taxodiaceae* between *Pinaceae* and *Cupressaceae*.

The genus *Macrobiota* Komarov (in *Not. System. ex Herb. Hort. Bot. Petrop.* iv. 180, 1923) was omitted, because Pilger treats it as 'Gattung unsicherer Stellung', which, he suggests, may be treated as an abnormal form of a *Juniperus* of the Section *Sabina*, until further evidence is forthcoming.

The genus *Amentotaxus* Pilger was accidentally omitted. As delimited by its author (in Engler's *Jahrbuch*, liv. 41, 1916) this is a monotypic genus based on *Podocarpus argotaenia* Hance, of western China, which Pilger transferred to the otherwise monotypic *Cephalotaxaceae*, under the name *Amentotaxus argotaenia* (Hance) Pilger.

In the Class Ginkgoariae an additional character of diagnostic value, mentioned by Penhallow (*A Manual of the North American Gymnosperms*, p. 109), is 'the presence of wood-parenchyma cells, which take the form of short idioblasts of lenticular form in longitudinal section, and are distinguished by the storage of crystals of calcium oxalate'. Such structures, he adds, are peculiar to the genus *Ginkgo*, 'in which they form a specific character of definite value'. In a transverse section the idioblasts may be seen, he says, scattered through the entire section without special reference to either the spring or the summer wood. He describes and figures them on p. 110, fig. 34.

The text-books of a generation ago stated broadly that the wood of the Coniferae ('excepting the genus *Taxus*') was characterized by the presence of resin-passages. Potter's translation of Warming's *Handbook of Systematic Botany* (reprint of 1920, p. 258) notes that: 'The characteristic feature of this Class [the Coniferae] is the abundance of *resin*, which is to be found in isolated cells (especially in the cortex), partly in intercellular glands or passages (both in the cortex and wood). *Taxus* is the only genus which has no resin.' Dr. Rendle (*The Classification of Flowering Plants*, vol. i, p. 85, 1904) refers to the schizogenously formed resin-passages of the Coniferae which 'are common in the cortex, and occur also in the primary and secondary wood'. Willis (*Dictionary of Flowering Plants and Ferns*, 5th ed., 1925) states that a 'very general feature (exc. *Taxus*) is the presence of resin passages in all parts of the pl.'. Such generalized statements are apt to mislead the unwary. Advances in knowledge of the wood-structure in Coniferae show that the presence of resin-

passages in the wood is not characteristic of *all* the genera, so that it cannot be relied upon, alone, to differentiate between *Coniferae* and *Ginkgoariae*, as would seem to be implied in my synoptical key to the two Classes. It would be more precise to say:

> Wood, cortex, or leaves with resin-passages or reservoirs (exceptions occur in *Taxus* and *Torreya*). Resin-passages occur in the leaves generally in the Coniferae.

Penhallow states (op. cit., p. 151) that: 'Those genera which are usually devoid of resin-passages in the wood, but some species of which may nevertheless contain resin-cysts in the young and vigorous growth, later produce single parenchyma elements in the wood which contain resin.'

Saxegothaea is the original spelling of this generic name, and under the International Rules it should be adopted in preference to *Saxegothea* as given by Bentham and Hooker (*Genera Plantarum*, vol. iii, p. 434) and some recent authors.

TIMBER-STAIN IN NORWAY SPRUCE

BY K. ST. G. CARTWRIGHT

(Forest Products Research Laboratory)

I READ with much interest the review by W. H. Guillebaud of the publication *Ästung* by Dr. Hans Meyer-Wegelin, which appeared in *Forestry*, vol. xi, No. 1, 1937. My attention was drawn in particular to the paragraph concerned with the prevalence of decay which was stated to follow on the practice of live pruning of Norway spruce. It was, as the reviewer stated, a curious omission that no mention was made of the species of wood-destroying fungi, and it is with the view of throwing a possible light on this that I write this note.

At this laboratory we have received Norway spruce poles from several different localities for pressure treatment. In a number of these poles a reddish-brown stain has been observed, the characteristic distribution of which is illustrated in Plate VI. A note concerning the cause of this stain and its effect on pressure treatment has already appeared in the *Report of the Forest Products Research Board for the Year 1935*. The fungus causing the reddish stain was identified by me as *Stereum sanguinolentum*, the stain being the result of an early stage of attack by this fungus, which later brings about a white stringy rot of the timber. There was strong evidence that infection occurred in the standing tree. Now many of the species of *Stereum* which attack the wood of the living tree gain entrance through broken branches, as, for example, *Stereum spadiceum*, which W. R. Day has stated to be the cause of a serious pipe rot of oak in the Forest of Dean. It is therefore, in my opinion, highly probable that one of the principal fungi concerned in the rot of Norway spruce subsequent to live pruning is *Stereum sanguinolentum*. It would be of interest to have the opinion of English foresters as to whether this type of decay is prevalent in plantations of Norway spruce and other conifers in this country, and it is with the hope of obtaining some data on this from your readers that I have written this note.

Red stain on Norway spruce caused by *Stereum Sanguinolentum*

PLATE VI

THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION. NOTTINGHAM, 1937

THE Hon. Nigel Orde-Powlett was Chairman of the sub-section and presided at all the meetings. Mr. T. Thomson was Secretary. The following is a list of the papers read:

Hon. Nigel A. Orde-Powlett (Chairman): 'The Present and Future of Estate Woodlands.'

R. C. B. Gardner: 'Preservative Treatment of Estate Timber.'

B. Pollard Urquhart: 'A Forest Working Plan for the National Trust.'

W. O. Woodward: 'Is there a possibility of a Timber Famine?'

Symposium on Mining Timber:

L. Holland: 'Mining Timber in Service.'

J. Macdonald: 'Future Supplies of Mining Timber from State Forests in Great Britain.'

J. T. Fitzherbert: 'Waste of potential Supplies in Private Woodlands.'

S. E. Wilson: 'Ascertained Costs of Pit-prop Operations.'

C. L. Jones: 'Merchanting of Mining Timber, England and Wales.'

W. R. Day and R. G. Sanzen-Baker: 'Forestry Problems near Industrial Areas.'

Discussion 'How the botanist can help the forester.' Opener: D. W. Young.

A. C. Forbes: 'The Relation of Macroscopic Tree-remains in Peat to Post-glacial Climate.'

SOCIETY'S AND OTHER NEWS

NOMINATIONS FOR OFFICE-BEARERS

The President, Vice-President, Editor of Journal, Business Editor, Secretary and Treasurer, and Auditor have all been nominated for re-election. For the vacancies on the Council there has been only one nomination, viz. Mr. Thomas Thompson, M.Sc., University College, Bangor, North Wales. Two more Councillors will have to be nominated and elected at the Annual General Meeting. As there is no competition for any office there will be no ballot.

EXCURSION TO BUCKINGHAMSHIRE AND BEDFORDSHIRE

The above excursion was held in conjunction with the Tenth Annual Meeting which took place at High Wycombe on 28 May 1937.

On the forenoon of 28 May a visit was paid to the Forest Products Research Laboratory, where the party was received by the Director, Mr. W. A. Robertson, and Mr. H. A. Cox. A tour was made of the different sections, including Wood Structure, Mycology, Entomology, Seasoning and Preservation, and Timber Testing; and the officers associated with the different sections described some of the investigations in progress. In the wood structure it was mentioned that it had recently been discovered that weight for weight the timber of hardwoods in temperate climates was tougher than that of tropical hardwoods. In the mycology section the recent work on the effect of blueing on the structural strength of timber was described, the results of which were published in *Forestry*, xi (1). In the entomology section members had the opportunity of 'listening in' to the Death Watch Beetle at work in timber. It was stated that after many years of work the life-history of this insect had been worked out in detail, and experiments are in progress to determine the influence of external factors, e.g. humidity, on it. Timber free from fungal decay and well-ventilated is not attacked.

In the afternoon a visit was paid to the Furniture Factory of Messrs. E. Gomme, Ltd. Mr. Gomme met the party and during the tour every stage from the timber yards to the complete furniture in the showrooms was seen. There was a particularly fine range of seasoning kilns, and other points of special interest were bending panels in vacuum, veneering, turning on automatic lathes, and shaping with high-speed routers. The home timbers used were oak veneers, and sweet chestnut for the cores of bulbous legs of tables. A large quantity of common spruce from Rumania was used for the built-up cores of panels, while Carpathian beech is preferred because of its mildness and low price. At the end of the tour of inspection the party were entertained to tea.

On 29 May a visit was paid to the Woburn Estate, where the party was met and conducted by Mr. C. P. Elliott, agent, and Mr. F. W. Mitchell, head forester. The major part of this estate is on the Woburn Sands of the Lower Greensand, but there are also extensive areas of silt soils, probably of fluvio-glacial origin. On the latter, oak and ash have been planted in mixture with spruce and larch. Plantations of these species planted in 1902 were seen which had been recently thinned, leaving pure hardwood stands. It was noted that there was a considerable development of epicormic branches on the more suppressed oak, but that the dominant trees were largely free of this blemish. *Aira caespitosa* was luxuriant in the ash stands. In a discussion Mr. Love-

grove and Dr. S. E. Wilson expressed the view that these plantations would be improved by underplanting from the points of view of health and development, but Mr. Mitchell, the head forester, said that the local experience was that good stands were secured without this. A range of good Scots pine plantations on the sand was seen of all ages up to a particularly fine one 100 years old. The type of Scots pine was good, the younger stands being from seed collected from the older trees of the estate. A considerable amount of thinning has been done recently in the middle-aged plantations. The estate nursery and sawmill were also of considerable interest.

In the afternoon many magnificent specimen and park trees, and an interesting collection of 166 different species, mainly conifers, were seen. Perhaps the most remarkable tree was a *Cedrus libani*, planted in 1746, whose girth at breast-height was 20 feet 9 inches. The tour ended with a drive round the extensive and lovely park where bison, llama, deer of several species, and many interesting birds from all over the world were seen. The party was then entertained to tea.

The excursion was the most largely attended that has been held, and the combination of lovely weather and interesting subjects made it very enjoyable. The Society is indebted to those responsible for the arrangements, and in particular the Director and Staff of the Forest Products Research Laboratory, Mr. Gomme of Messrs. E. Gomme, Ltd., The Duke of Bedford for permission to visit Woburn, and Mr. Elliot and Mr. Mitchell for conducting the party there.

CORRECTION AND SUPPLEMENTARY NOTE ON OAK FORESTS IN SOUTH-WESTERN IRELAND

Attention has been called to a mistake in my 'Note on Natural Oak Forests of South-western Ireland' in the last number of *Forestry*, xi (1). On page 9, under *Ground Cover*, it is stated that the dominant plant of the under-vegetation is *Vaccinium Myrtillus* and that, 'if Cajander's system of forest types, based on under-vegetation, were applied here, this particular site would probably come under the Vaccinium Type'. It should have been said that it would probably have come under the Myrtillus Type, because Cajander's Vaccinium Type is characterized by *V. Vitis-idea* and the sites characterized by *V. Myrtillus* are classed under the Myrtillus Type because he called *V. Myrtillus myrtillus nigra*.

While making this correction it might be of interest to add a further observation on the distribution of the type of forest described which has been made since the article was written. Natural oak forests, coppiced, occurring in the northern end of the Quantocks and hills south of Minehead in Somerset, on Devonian grit, are remarkably similar in composition to the oak forests in south-western Ireland. The main stand is of oak, with a small mixture of birch, scattered rowan (*Pyrus aucuparia*) in the intermediate story, and an understory of holly, with ground vegetation of *V. Myrtillus*. It is reasonable to suppose, therefore, that this oak-holly forest originally covered not only a large part of Ireland, as was considered likely when the article was written, but also considerable parts of England as well on suitable non-calcareous well-drained sites.

BARRINGTON MOORE

REVIEWS

Recent Work on Mycotrophy in Conifers.

(1) *The Physical Basis of Mycotrophy in* Pinus. By A. B. Hatch. Black Rock Forest Bull. No. 6, 1937.

(2) *The Relation between Mycorrhizae and the Growth and Nutrient Absorption of Coniferous Seedlings in Nursery Beds.* By H. L. Mitchell, R. F. Finn, and R. O. Rosendahl. Black Rock Forest Papers, vol. i, No. 10, 1937.

Reviews by M. C. Rayner

(1) In a short 'comment' appended to this monograph, Henry Schmidt, Professor of Forestry in the University of Minnesota, alludes to the 'confusion, controversy and disagreement that has persisted for fifty years in this field of enquiry' and pays a tribute to Professor Hatch's present contribution to 'a better understanding of a highly important and exceedingly complex scientific problem'.

In particular, the very full and able analysis of the older and less accessible literature should make the work of special value to students approaching the study of the mycorrhizal habit in trees—an intricate problem rendered more difficult by the controversial nature of much of the literature. The excellent illustrations, many of them original photographs now published for the first time, numerous tables and graphs, and an extensive bibliography also contribute to this aspect of the work.

Its purpose and scope is to present an irresistible case for the acceptance of Stahl's theory of mycotrophy in plants as set forth in *Der Sinn der Mycorrhizenbildung* in 1900. This paper of Stahl's is a classic and the theory of mycotrophy presented therein cannot be reviewed here. It led Stahl to the view that the basis of the mycorrhizal habit in plants is poverty in mineral salts, in contrast with the older view of Frank which emphasized the utilization of organic nitrogen. Hatch's own contribution to the theory is described as extending that of Stahl 'to explain in greater detail the mechanics of the superiority of mycorrhizal roots in nutrient absorption'.

The material presented is grouped under seven headings. The first, introductory, gives a general account of the phenomenon of mycorrhizal infection, its incidence in trees, with certain structural features of the individual mycorrhizal root of the ectotrophic type common to many trees. The general nature of the physiological problems involved with their practical application is illustrated by reference to soil inoculation experiments carried out in the course of forestry practice in various parts of the world.

The second section contains a critical review of the literature with the conclusions deduced from it by the author. This review, extending to forty-four pages, is a notable feature of the work and is marked by a freshness of outlook and clarity of expression rarely associated with the subject. As special pleading for his own view, the author's deductions from the literature could hardly be improved upon. On the other hand, the reviews of certain modern papers are marred by incomplete presentation of facts and are not free from a suspicion of personal bias.

The third section deals with Hatch's own studies briefly reviewed below. Certain aspects of the experimental work, with the author's conclusions thereon, are considered in greater detail in pp. 117–21 of this number of *Forestry*.

Then follow sections discussing the mycotrophic habit in general and detailing Hatch's interpretation of the known facts, another stressing the importance of his conclusions to forestry with an extended summary of the conclusions reached in the text, ending with a condensed restatement of the author's own opinions.

Let us turn now to Hatch's own researches. Since the publication of Melin's classical researches, the mycorrhizal habit in trees, its significance in nutrition, and the practical importance of its reactions on certain fundamental problems of silviculture have increasingly challenged attention. Experimental study of the subject presents many discouragements owing to the complexity of the biological problems involved and the difficulty of devising and applying a laboratory technique capable of supplying direct answers to these problems. Hatch had the advantage of working in Melin's laboratory, and since his return to the United States has published a number of papers relating to the mycorrhizal habit in conifers. In association with Doak he made a valuable contribution to correct understanding of the root system of pines, making clear for the first time the morphological identity of the short root as an organ *sui generis*, quite apart from its usual destiny as a mycorrhiza. Failure to realize this distinction, with, as a corollary, disinclination or inability to recognize true mycorrhizal structure, have undoubtedly contributed much to the persistent controversy that disfigures recent literature on the subject. Papers dealing with certain of the mycorrhizal associates of pines were published in 1933 and 1934.

There followed experiments leading to the use of improved culture chambers and pure culture technique for studying the nutrition of pine seedlings in relation with mycorrhizal activity. These experiments, redescribed and discussed in the paper now under review, are of value and interest. Although they failed to supply actual comparative data of the rates of absorption by mycorrhizal and non-mycorrhizal short roots, they provide reliable information concerning the production of mycorrhizas by pine seedlings under controlled conditions, and supply evidence for the direct absorption of peptone and nucleic acid by seedlings of pine without mycorrhizal equipment. The experimental technique undoubtedly marks an advance in the use of controlled methods for the study of mycotrophy, for which future workers should be grateful. The results obtained by the use of the improved culture chamber are elaborated by the author and supply part of the evidence on which his own interpretation and conclusions set forth in the present paper are based.

Attempts to evaluate the effect of mycorrhizas on the nutrition of pine seedlings in experiments designed to test the results following variation of the supply of inorganic nutrients in several types of soil led to negative results. Mathematical analysis did not yield evidence that possession of abundant mycorrhizas by a seedling led to increase in dry weight. This result was ascribed to the fact that good nutrient conditions discouraged mycorrhiza formation and vice versa within limits. Hatch concluded that neither the study of pine seedlings raised in different nutrient environments, nor that of selected seedlings in a single nutrient environment, but differing in mycorrhizal equipment (i.e. abundance), could supply the critical data required. To provide such proof seedlings must be grown in an environment where infection by mycorrhizal fungi is the only variable. With this conclusion the reviewer fully concurs.

Here the matter stood when in 1936 Hatch realized the experimental potentialities implicit in the study of American prairie soil from this point of view. Transported soil from a treeless prairie region in Wyoming, mixed with sand, was used for pot cultures of White pine (*Pinus strobus* L.). After sterilization, twenty germinated seeds were placed in each of six containers in August 1936 and the pots protected from

contamination by fungus spores. The experiment was designed to test whether the ectotrophic mycorrhiza-formers of pine were lacking, and, if so, whether they are essential to tree growth in such soils. By November, all seedlings were 'small, yellow, and unthrifty, and had not developed mycorrhizas'. Three of the six containers were then inoculated from pure cultures of four mycorrhiza-formers. In the following spring, marked differences became apparent in the seedlings in inoculated and control pots; the plants were harvested and examined in late May and early June. Seedlings from the inoculated pots possessed abundant mycorrhizas, and were larger, more vigorous, and with longer and greener needles than the controls; the latter formed no mycorrhizas and presented obvious symptoms of starvation. (The structure of the short roots formed by the control seedlings is not described.) The comparative data relating to dry weights of the seedlings, the root-shoot ratios, with the values for nitrogen, potassium, and phosphorus contents obtained on analysis are presented in tabular form and offer a striking contrast in the two experimental series. From these values are calculated the averages for seedlings from pots of inoculated and pots of control seedlings. These are as follows:

	Dry wt. of seedling in mg.	*Root-shoot ratio.*	*Nitrogen.*		*Phosphorus.*		*Potassium*	
			mg. per seedling.	*Per cent. of dry wt.*	*mg. per seedling.*	*Per cent. of dry wt.*	*mg. per seedling.*	*Per cent. of dry wt.*
Averages from two pots of mycorrhizal seedlings	404·6	0·782	5·00	1·241	0·789	0·1957	3·02	0·744
Averages from three pots of non-mycorrhizal seedlings . . .	320·7	1·138	2·69	0·849	0·236	0·0735	1·38	0·425

The increased absorption of nitrogen is 86 per cent., of potassium 75 per cent., and of phosphorus 234 per cent. in mycorrhizal as compared with non-mycorrhizal plants.

The average values for nitrogen, potassium, and phosphorus in the control seedlings are below the corresponding values quoted for seedlings of White pine 'grown in any soil'; they approximate, in the cases of nitrogen and phosphorus, to those found in experimental seedlings deprived of these elements. (Mitchell, *Black Rock Forest Bull.*, No. 5, 1934.)

In Hatch's view, 'this evidence is conclusive in showing that the White pine seedlings grown in this prairie soil did not obtain sufficient nutrients to support normal growth when mycorrhizal fungi were absent'.

These experimental results obtained with prairie soil, designated by the author at the time as 'few and exploratory in scope', have been described in detail because of the critical importance now assigned to them. On the experimental side they form the main individual contribution—as distinct from those parts of the argument deduced from earlier experiments or based on theoretical considerations—in support of the detailed theory of mycotrophy in *Pinus* put forward here.

Hatch discusses the influence of mycorrhiza-formation on root development in pine seedlings, supplying evidence that the abundance or otherwise of mycorrhizas in normal forest soils is directly influenced by the amounts and availability of nitrogen, potassium, phosphorus, and calcium. Many of the observations cited are in direct agreement with

those of other observers in this country, although it seems possible that other soil factors may also play an important part. In themselves, they provide strong presumptive evidence that the mycorrhizal habit in tree seedlings is directly bound up with their normal nutrition and growth.

Hatch's further conclusion that 'the susceptibility of short roots to infection by mycorrhizal fungi in soil and in pure culture experiments is apparently controlled by the concentration of nutrient elements within the two symbionts' is of particular interest, since it co-ordinates many confusing and discordant observations and provides a clue to the confusion in the literature. The application of Åslander's results (relating the magnitude of the absorbing surfaces in plants with the internal concentration of nutrients) to explain the greater efficiency in salt absorption of mycorrhizal as compared with non-mycorrhizal roots is of special interest in this connexion. If Hatch can confirm Stahl's measurements in respect to the relative concentration of nutrients in mycellium and root-cells, he will provide a physical basis for the mechanism of mycotrophic exchange which may well prove to be the 'crux of the mycorrhizal problem'. To the reviewer, it has long been apparent that normal mycorrhizal infection increases the surface area of the short roots through which absorption takes place. Hatch's analysis of the various ways in which this increase in area is brought about is lucid and convincing.

(2) This paper describes seedling experiments with White pine (*Pinus strobus* L.) and Red spruce (*Picea rubra* Link.) carried out in a 'very infertile' artificial soil mixture consisting of sawdust and sand with a little clay. Certain beds were unfertilized; in others the nutrient environment was varied by addition of nitrogen, potassium, and phosphorus in several combinations and varying amounts. During the first season each growing bed was inoculated with 50 grammes of soil known to be 'rich in mycorrhizal fungi'. The control beds (unfertilized) were not so inoculated, but during the second season became locally infected through natural means, thus offering an unexpected supply of comparative material from the same nutrient environment.

Great care was evidently exercised in the details of these experiments—selection of seed, preparation of seed-beds, &c. The number of control beds, 3 in 50 in the case of White pine, 1 in 22 in that of spruce, can hardly be regarded as adequate, although in the reviewer's opinion this does not affect the conclusions reached by the authors in respect to the effects of mycorrhizal activity.

In Mitchell's earlier experiments on the effects of variation of the supply of nutrients to seedlings of White pine, there was placed on record a conspicuous lack of agreement in the root responses of plants grown in sand and soil respectively ('Pot Culture Tests of Forest Soil Activity', *Black Rock Forest Bull.*, No. 5, 1934). Inasmuch as the soil cultures all received additions of fresh soil at sowing, and the experimental seedlings showed mycorrhizal development varying in degree with the nutrient conditions, it appeared likely to the reviewer when the paper was published that the existence of mycotrophy, correlated with such mycorrhizal development, was the disturbing factor in the results observed. Accepting this interpretation, it followed that this type of experiment could not be employed for direct comparisons of growth reactions based on variation in the supply of nutrients.

This possibility was evidently considered by the author, but Hatch, who examined the material from this point of view, could find no evidence that 'mycorrhizae increased dry weights'. He did, however, in spite of the inconsistencies due to variation in nutrient environment, interpret the mycorrhizal attack in soil, as compared with sand,

as one that 'increases the absorbing area of the short roots'. The significance of these observations in relation with Hatch's subsequent conclusions and with those of the writer of this review are apparent (see p. 129).

The paper now under review confirms the accuracy of the diagnosis and conclusions just offered, since mycorrhizal and non-mycorrhizal plants of White pine and Red spruce from the same nutrient environment were accidentally available. The mycorrhizal plants were obtained from unfertilized inoculated control beds which became infected locally in patches with mycorrhizal fungi apparently by some natural means. Such infected areas were easily identified by the size, vigour, and improved colour of the seedlings. With these features was associated the development of typical mycorrhizas, whereas poor seedlings from other parts of the same bed showed only short roots of non-mycorrhizal character. Remarkable differences in the total dry weights and the content of nitrogen, potassium, and phosphorus at the end of the second growing season are recorded for the two types of seedling, such differences being greater and appearing at an earlier stage of growth in Red spruce than in White pine.

Although these experiments do not, in themselves, afford conclusive proof of causal relation—as distinct from coincidence—between mycorrhizal activity and improved nutrition in young conifers, they are in complete accord with results obtained in this country by the writer and by Hatch in America. The author's conclusion that it is extremely doubtful if they 'can be explained upon any other basis' is fully endorsed by the writer of the present review.

Deutschland. By H. Göring and Others. *Zeitschrift für Weltforstwirtschaft*, vol. iii, No. 11/12, August/September 1936.

Review by W. H. Guillebaud

THE greater part of this large volume of over 400 pages is devoted to a review of the present position of forestry in Germany. It is in the form of a series of short papers by leading German authorities which cover almost every aspect of the industry. The first sixteen papers form a general introduction to the theory and practice of forestry in Germany, while the later articles, totalling ten in all, are more of the nature of regional studies reviewing current trends in the more important states, or regions, e.g. Bavaria, the Spessart, &c. There are also one or two papers describing certain private forests of outstanding importance such as Bärenthoren and Hohenlübbichow. A more or less adequate summary in English and French is appended to each article. Considerations of space preclude individual reference to all the papers, but the reviewer has attempted to deal with the more important.

The Reichsforstmeister, General Hermann Göring, contributes the first paper under the heading 'Deutsches Volk—Deutscher Wald'. He states, as a basic principle of national socialism, the demand that all branches of industry should exist for the people and must serve the people. The application of the principle of forestry would appear to involve among others (1) the freeing of forestry from agriculture and the setting up of an independent forest administration; (2) the linking up of forestry with the protection of wild animal and plant life; (3) inclusion of the timber industry in the Ministry of Forestry and regulation of timber prices; (4) a more biological attitude towards forestry in general, tending to discard such notions as the financial rotation which led in the past to unduly rigid and unnatural systems of forestry; (5) improvement of yield from the forests with the object of rendering the country less dependent upon imports of timber.

Göring's introduction is followed by a paper by Generalforstmeister von Keudell, the executive head of the new forest administration. The paper deals with the building up of the German forest of the future. The essential points are: (1) The forestry of the nineteenth century resulted in a great destruction of the pure broadleaved and the mixed forests of Germany which were replaced largely by pure coniferous forests. (2) Pure coniferous forestry has led to excessive damage from epidemics of all sorts and from fire, besides resulting often in soil deterioration. (3) The aim now is to replace the existing pure forests by mixed woods and to concentrate on the production of quality rather than quantity. (4) Clear felling is to be confined to the necessary minimum, e.g. to the removal of worthless crops and especially of stands of unsuitable seed provenance. (5) Forestry must give up the old idea of management by area and regard, rather, the single tree as the unit of management.

The succeeding paper by Eberts deals with the organization of the new Ministry of Forestry which, it is interesting to note, includes as one of its main divisions the spread of national social principles in the sphere of forestry, defined in a later article of the series as 'the philosophical education of all those employed in German forestry, from the forest proprietor down to the labourer'.

An article follows by Professor Franz Heske on German forestry; this is largely statistical but contains a statement on the German need for colonies to augment their timber supplies. Dr. Mantel of Tharandt then deals with state control of the forest and timber industry in Germany and refers to the new laws passed in 1934 prohibiting large-scale clear fellings and dealing with seed control.

Ministrialrat Parchmann discusses the economics of the European timber industry with special reference to Germany. He concludes that the principle of maximum returns is one of the main causes of the disorder and instability that prevail in the forest and timber industries, and that it is necessary to amalgamate the forest and lumber industries, regulate sawmills and factories, and also wages and prices.

Dr. Gernlein of Berlin has a short but interesting paper on new uses of wood in which he states that modern invention has enormously increased the uses of wood and its products. He considers that it has now a place among raw materials of equal importance to that of iron or stone.

The succeeding paper by Dr. Ebner of Munich deals with extraction of timber from the forest. Then follows Professor Abetz of Freiburg on the development of forest management in Germany. Abetz points out that the modern, more fluid, ideas of silviculture will be no less dependent that formerly upon a proper system of assessment of growing stock and control of yield.

Professor Rubner of Tharandt has contributed a paper on the new methods and aims of silviculture in Germany, which elaborates the principles laid down by Herr von Keudell, namely, management by individual selected trees, reduction to the minimum of clear felling, and the creation of uneven-aged mixed forests. A good deal of the same ground is also covered by Professor Vanselow of Freiburg, who discusses the methods and aims of regeneration. The object of the new silviculture is to obtain natural regeneration wherever possible, and it is believed that improved methods will greatly extend its use throughout Germany.

Of the remaining papers, those by Professor Wiedemann on forest research in Germany; by Generalforstmeister von Keudell on thirty-four years in control of the Forest of Hohenlübbichow; and, Bärenthoren, an experiment in modern German forest management, by Forstmeister Weck of Eberswalde, are of special interest, but there are also a number of useful articles, among which the following may be mentioned:

'Silvicultural Conditions in the Oberland of East Prussia', by Oberforstmeister Niggl.
'Spruce Forestry in the Harz', by Forstmeister David.
'Forestry in Bavaria', by Dr. Künkele.
'The Production and Supply of Timber in Bavaria', by Mantel.
'Notes on Silviculture in Bavaria', by Dr. Rebel.
'The Spessart', by Orth (some very fine photographs of the old oak forests are included).
'The Management of the State Forests of Saxony', by Dr. Blanckmeister.

In conclusion it may be observed that the volume as a whole gives a clear picture of the very interesting recent developments in forestry thought in Germany. These developments seem bound to influence forest policy in other countries besides Germany, and foresters throughout the world will watch with sympathy and interest the important changes now being introduced.

Insects of the British Woodlands. By R. Neil Chrystal, M.A., D.Sc. Frederick Warne & Co., Ltd., London, 1937. Price *7s. 6d.* net.

Review by R. C. Fisher

In the first volume of this Journal, published ten years ago, a brief account of the position of forest entomology in Great Britain at that time was given by Professor J. W. Munro, whose work, when entomologist to the Forestry Commission, established the importance of insects in relation to the progress and development of forestry in this country. Although advances have been made in the study of many of the forest insect problems outlined by Professor Munro, the information obtained has been published in the form of bulletins and leaflets from institutions or government departments, and in contributions to scientific journals. A book covering the field as a whole, in the light of recent knowledge, has long been overdue, and indeed has frequently been called for by those concerned in the prevention and control of insect damage to trees and timber, since no text-book of forest entomology in Great Britain has been written since that by A. T. Gillanders, published in 1908 (second edition, 1912). Few can have seen more clearly than Dr. Chrystal the need for such a new publication, and the place it would at once fill. It is fortunate, therefore, that the preparation of this welcome addition to forest literature should have been undertaken by him, as one who not only worked in close association with Professor Munro in the early days of forest entomology in this country, but succeeded him at the Imperial Forestry Institute, Oxford, and has a wide knowledge of our forest insect problems.

It is explained in the preface that the book is based on a 'manuscript originally prepared for use in one of the Forestry Commission's training schools for foresters'. It is, therefore, to be expected that the subject-matter would be presented in a form especially suitable for easy and rapid identification of different types of forest insects and the damage they cause, and also include methods of their prevention and control. This purpose has been kept well in mind throughout the book which, as the author hoped, supplies the need 'for an elementary treatise on the insect life of the British woodlands', but at the same time is a valuable field handbook which will be of the greatest use to the practical forester. This is achieved principally by the emphasis that is laid on the importance of an accurate knowledge of the biology of the insects concerned, and their relation to forest practice, whether in the nursery, in newly formed young plantations, or in mature woods. For instance, in the opening pages of Chapter I

(Introduction), the insects dealt with subsequently are classified into biological groups according to their habits, viz. defoliators; borers in buds, leaves, shoots, or seeds; gall makers; bark feeders; wood borers; root feeders; parasites and predators. Thus, even at the risk of frequent repetition, the author establishes his main thesis as a biological approach to the study of the species described.

The remainder of the first chapter, which might usefully have been completely separated from the introductory remarks, deals briefly but adequately with the classification of the Arthropoda—due comment being made in passing upon the few members of the Arachnida and Myriapoda (spiders, millepedes, and centipedes) which are of forest interest or importance—and gives, with drawings, a short but very essential description of insect development and structure, with special reference to those parts which are of taxonomic value. A simple family key for identification of larvae of the principal types of forest insects is also included, and being based not only on morphological characters but also on habits and type of damage caused is especially useful. The preparation of such a key is no easy matter, and to be of practical value must be strictly accurate. Attention is, therefore, drawn to an error which on page 35 has crept into the paragraphs under Section B (2) (ii) describing the larvae of the Siricidae. In comparing these with some Cerambycid larvae the description 'legs more prominent' should read 'legs less prominent'. Interpretation of the key is facilitated by drawings of different larval types, amongst which the Lyctid larva does not clearly show the diagnostic character of the enlarged spiral on the eighth abdominal segment; moreover, the thoracic spiracle should be on the prothorax and not on the mesothorax, as illustrated. A brief synopsis of the different orders of insects of forest importance is given at the close of this chapter, and these are dealt with in greater detail in succeeding chapters.

The Orthoptera (cockroaches, locusts, grasshoppers, crickets, &c.), Dermaptera (earwigs), Odonata (dragonflies), and Neuroptera (lace-wing flies and snake flies) contain few insects of prime importance, and are dealt with shortly in Chapter II. A comprehensive account is given, however, of the Hemiptera (bugs, aphids, chermes, scale insects), which include several injurious species. The complex life-cycle of the conifer gall lice (Adelginae or Chermesinae), with their primary and secondary host trees, is clearly described, and reference to Cameron's recent work on these insects in this country shows how up to date is the information included in the book.

The Lepidoptera (butterflies and moths) are dealt with in Chapter III, an outstanding feature of which is the tabular summary of the important species grouped according to the type of damage caused. Although, as is to be expected, most attention is given to such insects as the oak leaf roller, *Tortrix viridana*, and the pine shoot moth, *Evetria buoliana*, which cause considerable damage in this country, mention is also made of species responsible for great havoc on the Continent, for instance, the nun moth, *Liparis monacha*, and the pine looper, *Eupalus piniaria*. These insects occur in Great Britain, but so far have not caused the widespread defoliation which, periodically, is such a feature of the coniferous forest areas of central Europe. Dr. Chrystal suggests, however, that 'many of our forest areas at the present time are not yet at the critical age when such widespread attacks develop, and we must wait a few years more before we congratulate ourselves on our immunity'.

The Coleoptera (beetles), to which Chapters IV and V are devoted, include a greater number of insects of forest importance, harmful and beneficial, than any other insect order. The author is to be specially congratulated on the manner in which he has succeeded in compressing into ninety-seven pages the essential facts of life-history, habits, and control of a number of beetles truly representative of the different biological

groups into which these forest insects can be arranged. Whenever possible, simple keys and biological synopses have again been included which will be of great value to the non-specialist. In an effort not to overburden the general reader with detail, short technical descriptions of the more important species are given separately in Appendix I, but it is a moot point whether such an arrangement is altogether desirable. The reviewer believes that this appendix could have been omitted and the information contained in it included under each species in the different chapters, especially as some repetition is inevitable.

Of the insects dealt with in Chapter IV, particular attention is given to the weevils, notably *Hylobius abietis*, which is generally regarded as one of the most important forest pests in Europe. Control measures involving the use of bark, billet, and pit traps are discussed at length, and passing reference is made to studies now in progress, to investigate the significance of the insect parasites of this weevil as agents in its control. This and other work on the biological control of forest insects, carried out at the Farnham Royal Laboratory of the Imperial Institute of Entomology, is described in greater detail in Chapter VIII.

The bark-beetles and pinhole borers (Scolytidae and Platypodidae), the longhorn beetles (Cerambycidae), the chafers (Scarabaeidae), and the Lucanidae are discussed in Chapter V, which also includes brief mention of powder-post (Lyctidae) and furniture beetles (Anobiidae), of greater importance in timber yards, manufacturers' premises, buildings, and furniture than in the forest. The common furniture beetle, *Anobium punctatum* De G., is described under its synonym *Anobium striatum* Oi.

Chapters VI and VII deal respectively with Hymenoptera (saw flies, wood-wasps, parasitic forms, &c.) and Diptera (two-winged flies, mosquitoes, gall midges, and predacious forms). A particularly interesting part of the former summarizes Dr. Chrystal's studies of the *Sirex* wood-wasps and their parasitism by the Ichneumonid, *Rhyssa persuasoria*, and the Cynipoid, *Ibalia leucospoides*.

In the final chapter (VIII) the conditions under which insect outbreaks arise in forests are briefly reviewed, and special mention is made of the comparative value of mixed and pure stands in relation to their susceptibility to insect attack, the importance of sound silviculture and the effect of fire and storm damage, and felling operations upon bark-beetle outbreaks. Although methods of prevention and control have in most cases already been mentioned in the earlier chapters, these are with advantage again discussed in general, and a distinction is drawn between natural control—as brought about by climatic conditions, by the operation of biological factors such as the feeding of insectivorous animals and birds, to which attention is specially directed, attack by insect parasites, predators and diseases—and artificial control, as attempted by modifications of silvicultural practice or by the application of insecticides and fumigants. In this latter category, examples are given of treatments applicable on a small scale for the control of specific insects, the various methods described being dealt with under the different insect orders concerned.

Two appendices are added, the first containing descriptions of some of the more important species; the second, a list of the forest insects described in the text, arranged in biological groups, is one of the most useful sections of the book, acting not only as an additional index, but also as a preliminary key to the identification of the species, according to host trees.

The text is illustrated throughout with numerous excellent black and white drawings by Mr. J. S. Shaw, and by plates of photographs by Mr. L. A. Clinkard, both of whom are to be congratulated on their work. The surprisingly low price of the book has no

doubt to some extent determined the arrangement of the photographs on the plates, several of which are far removed from the relevant context. The value of many of the illustrations could have been greatly increased by some indication of the magnification to which they are drawn. For instance, without such information no comparison can be made between the size of the different insect larvae figured in plate 8.

A short bibliography is given, chiefly of recent forest literature in this country, but it could usefully have been extended to include references of value to those wishing further information on forest entomology in general or upon some of its specific problems. The printing of the book is excellent, and its freedom from errors is proof of the care which has been taken by author and publishers alike in its preparation. Both are to be congratulated on the publication of a book which, because of the very readable presentation of its subject-matter and no less because of its moderate cost, should be in the hands of every forester and will command the attention of the wider public, interested in natural history as a whole.

The Relationships of the Humus-cover to the Age and Composition of the Stand in Northern Spruce-forests of the Bilberry Vaccinium Type and the Influence of the Humus-cover on the Regeneration and Growth of Woodlands. By Henrik Hesselman. *Meddelanden från statens Skogsförsöksanstalt*, vol. xxx, Nos. 3 and 4. Stockholm, 1937. Swedish with German summary.

Review by G. K. Fraser

THIS investigation is a continuation of earlier work by the same author reviewed in previous numbers of this Journal. In this paper the subject is reviewed and studied from the soil-biological standpoint.

The treatment of the old spruce forests of Norrland (north Sweden) has always been a question of considerable importance in Swedish forestry. Two different methods of regeneration have been advocated—the selection system and clear-felling and regeneration in strips. The advantages of clear-felling have been demonstrated by the author in earlier work; here, fundamental interrelationships of crop and humus-cover are investigated by laboratory analyses and tests, and by field observations and experiments. The methods used are first described, followed by general description of the forests chosen as subjects of study, together with the vegetation and humus-cover of these. These are chiefly spruce, spruce and fir, and spruce, pine, and birch woods of the *Vaccinium* type with *Vaccinium Myrtillus* and *V. Vitis-Idaea* the chief species, and having a somewhat variable humus cover.

The depth of humus cover tends to increase with the age of the stand, while at the same time it changes from a more open mull-like type under young stands (especially with birch) to a denser, more fibrous and tough type under old stands. Similarly, available lime and nitrogen-contents decrease with the age of the stand and where birch is absent. Variation in acidity is somewhat irregular, the more so in young woods and where there is birch. pH value is lower in the H layer than in the F, is lowest in June and highest in July and August. But acidity is considered to be of secondary importance, although on the whole it decreases on more fertile soils. This fact is connected with the greater content of lime in more fertile humus and its greater abundance of basic buffer bodies, also associated with birch in the crop. Study of the cellulose content and of the cellulose-decomposing power of the various humus types gave negative results.

The nitrogen status of the humus-cover is shown to be of the greatest importance in

relation to fertility, and the deficiency in available nitrogen in humus of old stands as compared with that of young stands is shown by the relative rate of growth of plants in humus-sand cultures. This point is further established by means of field experiments in which the soil of the forest was irrigated with a weak solution of ammonium nitrate. This treatment not only improved the appearance of the crop almost immediately but in time resulted in increased growth of the crop and in alteration of the ground vegetation and humus-cover towards an improved type, and, as described in a chapter by Bjorkman, improved the mycorrhizal form of the tree roots.

Not only are such differences characteristic of young and quickly-growing stands contrasted with old over-mature stands and groups of trees, but during the development of stands from the unstocked condition, alterations from better to worse conditions of the humus-cover tend to take place. In youth, especially after burning and where birch comes up with the conifers, the humus is of the mull-like type with all the chemical characteristics of the mull-like humus, but as time goes on the soil will deteriorate, as can be shown by means of tests in sand-humus cultures. It is shown that the beneficial effects of clear-cutting and scattering the brush over the ground, and especially of burning the brush and the old humus surface, are to be ascribed to two causes which can be produced under laboratory conditions: (1) the increase in the ash-content of the remaining humus which is associated with better nutrition of seedlings, herbage, and soil micro-flora, and (2) the partial sterilization by the heat of burning which promotes biological activity of the soil.

By incubation experiments it is shown that an increase of mobile nitrogen results from treatment of the humus with nutrient solutions and by partial sterilization (e.g. by heating for some hours at 60° C.), and that nitrification of ammonia or organic nitrogen takes place in naturally good humus without further treatment than this, while, in addition, poor humus types must be inoculated by means of a nitrifying soil in order to obtain the best results. That is to say poor humus types are deficient not only in the conditions necessary for the liberation of unavailable nitrogen but also have lost the organsims which produce nitrification. This explains the occasional failure of burning as a method of soil improvement on felled over-mature forest soil. Inoculation is required as well as burning, otherwise only ammonia is formed, and this may be lost as a result of the basic action of ashes from the burning. Nitrifying bacteria would prevent this loss by converting ammonia to nitrate which is held by the ashes.

Climatic conditions are not only directly important as regards the results of felling and burning but also indirectly, for example, in the inclement weather of north Sweden biotic soil processes must be slow. Therefore it is advisable to make as much use as possible of the not infrequent warm summer seasons.

Reference is made to the work of Gast (see this Journal, vol. xi, No. 1, p. 70) in connexion with the growth of seedlings in relation to available nitrogen and light-intensity, and the moral is drawn that in northerly regions dense stocking of selection woods is not good practice, since low light-intensity may be compensated for by attention to the quality of the humus, and both are dependent on absence of dense shade. Hence clear-felling in strips is preferable to selection, provided the strips are not too wide, a subject dealt with in a recent paper by the author (*V. Medd. Jr. Stat., Fors.* No. 28, p. 731, 1935) but still requiring further detailed study. The question of thinning in even-aged stands is also to be considered in relation to the humus-cover.

For all problems which arise in the treatment of the northern spruce forests the key to the best practice is to learn from the natural processes what should be aimed at and what should be avoided. This might be taken as a rule for forest practice in general,

and there can be no doubt that the series of papers by Prof. Hesselman and his co-workers, of which this is the latest, have provided much information regarding the natural characteristics of forest soils, information which can often be applied directly to our own conditions and to the improvement of our own practice.

Der Grossanbau der Douglasie im Gadower Forst ('The Cultivation of Douglas fir in the Forest of Gadow'). By L. Adolph. *Forstarchiv*, Heft. 11, 1936.

Review by J. M. Murray

THE forest of Gadow lies between Wittemburg and Lenz. About two-thirds of its area rests on alluvial layers which vary from pure peat to alluvial sand. The soil is a humose sand. Pan occurs in places. The water-level lies at a depth of 39 to 59 inches. The other third rests on diluvial layers with here and there terminal moraines and overlaid by sand dunes. The annual rainfall is seldom over 500 mm. The height of the forest above sea-level varies between 56 and 131 feet. Late frosts are not uncommon and the thermometer may register as low as —6° in May.

The cultivation of Douglas fir and other exotic conifers was started in 1865. By 1890 the owner had decided that the Green Douglas fir was the best of all the species tried. He based this opinion on the rate of growth in height and diameter and on the ability of the tree to recover from injury. The trees were planted as isolated specimens and one of the largest has reached, after 71 years' growth, a height of 108 feet and diameter at breast height of 3·4 feet.

In 1920 when Adolph came to take charge there were 42 acres of Douglas fir planted in Gadow Forest. These ranged in age from 1 to 60 years and occupied sites that were representative of the conditions in the forest. Satisfied from the results obtained in these plantations that the tree was suitable for further cultivation, Adolph commenced planting it to a greater extent. As a result of this there was in 1936 an area of 304 acres of Douglas fir. Owing to the risks from frost the Douglas fir is planted under some kind of shade. It is planted under short-boled, poor oak growing in unsuitable localities and in holes made in pine woods by root fungi. The latter are prevalent among pines planted on old ploughed land. While the Douglas fir has not been immune from attack by *Fomes annosus* only isolated trees have been killed by it and that mainly when the trees were young. Douglas fir has been entirely satisfactory as a repairing crop and at 25 years old it has reached the same height as 50 to 60 years old Scots pine. In a similar manner blanks in oak stands have been closed with Douglas fir and mixed with beech; it has also been used in the transformation of areas of pine of poor races. Another feature that commends the Douglas fir is its immunity from attacks by *Noctua griseovariegata*. It is attacked by *Liparis monacha* but not killed. Where owing to attacks by these moths production has fallen to 0·6 the woods have been under-planted immediately with Douglas fir in mixture with one-third beech and *Prunus serotina*. The broad-leaved trees are included as soil improvers. Since 1922 Douglas fir plants used in Gadow have been grown from seed collected off selected trees in the forest. Nurseries are made under shade and that of the pine is considered to be the best; areas with free, humus-rich soils are chosen for the seed beds and heavy soils are considered to be unsatisfactory. The seed is sown in autumn, even in November or December if the soil is open. This practice prevents the seed from lying over for a year. Plants are lined out at 8×10 inches. A somewhat wider spacing is considered to be better. Planting out in the forest is carried out as soon as the risk of hard enduring frosts is past. The pits are

opened in autumn. Planting is completed by turning the turf upside down on the top of the pits to conserve soil moisture.

At first the timber was looked on with suspicion. The small quantities produced were sold in the local markets. Now the demand and the supplies are greater, and Douglas fir timber is sold with lots of spruce and Scots pine. It is used for ladder poles, telegraph poles, aerial masts, flag poles, and in the construction of silos. Adolph expresses the opinion that it is an excellent timber and at least equal to European larch.

It is interesting to know what a German forester has to say of the Douglas fir and the uses to which he puts the tree in his forests. In this country opinions are varied. For many years it was regarded as one of the main forest trees of the future. To-day it is not so popular. The difficulty of selling small sizes (in Scotland at least), its liability to wind-throw, and the many stands of badly shaped young trees had something to do with this. In addition the timber of older trees grown openly was not favoured by merchants. Perhaps we have been unduly influenced by results which were due to bad silviculture and by the opinions of merchants who had worked only with timber not produced under forest conditions.

Structure, Occurrence, and Properties of Compression Wood. By M. Y. Pillow and R. F. Luxford. Technical Bulletin No. 546. U.S. Dept. of Agriculture, Washington, 1937. Pp. 32 and 9 plates. Price 10 cents.

Review by E. W. J. Phillips

IT has long been known that abnormal wood is produced on the lower side of leaning conifers, and in the present publication an account is given of the various natural conditions under which this so-called 'compression wood' is formed, its properties, and the effects of its presence on the utilization of timber.

Affected trees are mostly characterized by markedly eccentric growth-rings accompanied by unusually large amounts of summerwood in the wider portions of the rings. Compression wood causes a number of practical difficulties in the utilization of timber owing to its peculiar physical and mechanical properties. Its relatively high density introduces difficulties in nailing and in working under tools, and more remarkable is the distortion and cross-checking brought about by the excessive longitudinal shrinkage of the wood. Of the mechanical peculiarities the comparatively high compressive strength in the green condition is significant in view of the buttressing role attributed to compression wood in the standing tree. Weight for weight, however, such wood is stated to be weaker, on the average, than normal wood in most strength properties both in the green and air-dried conditions.

While the circumstances bringing about compression wood formation are fairly well recognized, the mechanism through which wood cells of a fundamentally abnormal nature are produced in response is obscure. That both the micellar structure of the cell-walls and their chemical composition differ markedly from the conditions found in straight-grown timber has been clearly and repeatedly demonstrated, and it may be that differences of this type, though less pronounced, are responsible for much unaccounted variation in the properties of apparently normal timber.

The actual stimulus causing compression wood formation is still in doubt; experiments suggest that gravity rather than longitudinal compression is responsible, but neither affords an adequate explanation in all cases. A limiting factor in the process is growth vigour; slowly growing pines, although leaning, form no compression wood and, in general, for a given inclination of the trunk the production of compression wood

is proportional to growth rate. The distribution of this abnormal wood within the trunk depends on the manner in which leaning has taken place and may be present on one side throughout the tree, or limited to certain lengths or sectors corresponding with local or temporary inclination. Wood near the pith is commonly affected owing, presumably, to the flexibility of the slender young stem.

The general aim of silvicultural measures for the control of compression wood formation is to ensure that all stems remain vertical throughout their growth. Once leaning or curvature takes place compression wood is likely to be formed; subsequent straightening will not remove the defect, and the sooner inclined stems are removed the better. It is believed that overcrowding in young stands predisposes to the formation of leaning stems more so than understocking. Large and irregular openings in the canopy are also to be avoided in order to limit wind action.

Compression wood is recognized as a common defect in the softwoods of North America and control measures have been formulated against its production, but it is not to be dismissed as a misfortune peculiar to that country. The same effect is not uncommon in home-grown softwoods, particularly in rapidly grown material, and difficulties may be anticipated where such timber is used for anything but very rough work.

The authors of this bulletin are to be congratulated on the practical way in which they have attacked the problem of compression wood, and the work described forms an admirable example of the utility of co-operative investigations in silviculture and timber technology.

Spring Frosts. Forestry Commission Bulletin No. 18. H.M. Stationery Office. Price 2*s.* 6*d.* net.

Review by Thomas Thomson

SPRING frosts are one of the most frequent causes of injury to young plantations and forest nurseries. The authors of this bulletin, Messrs. W. R. Day and T. R. Peace, of the Imperial Forestry Institute, Oxford, have already published work on the subject of the *Experimental Production and the Diagnosis of Frost Injury on Forest Trees* (Oxford Forestry Memoir, No. 16, 1934), and research has been going on for the Forestry Commission during the past eight years into frost as a cause of diseases in forest trees. The widespread damage done by the May frosts of 1935 caused so much alarm that it was decided to study the whole subject in detail. Data were, therefore, collected of the damage done by these frosts to trees and shrubs all over the country with as much detail as possible of the topographical and other conditions. These data, together with others on the subject of frost found in the literature, have been worked up into a very interesting and instructive memoir.

The first part of the bulletin is devoted to a description and discussion of the meteorological, topographical, and other conditions which lead to the occurrence of severe spring frosts. The fact that certain localities are subject to more frequent and more severe frosts than others in the same district is well known. Frosts are due in the first place to radiation of heat from the soil and its covering vegetation, leading to a fall in temperature of the radiating surface and the air in contact with it. If the air is already cold owing to the inflow of air from more northerly regions where winter conditions still exist, the fall in temperature may be very considerable. The lowest temperatures are found near the radiating surface. This is the reason why small plants and the lower parts of large ones are, in general, more exposed to frost damage than higher ones. The authors discuss the various factors which influence radiation and the chilling of the air.

The local variations in frost intensity are, however, shown to be due in the main to the drainage of the denser, colder air down slopes and its accumulation in hollows, valleys, &c. The lower parts of slopes are more liable to extreme frosts than the upper parts, because the chilled air flows off the latter. In deep valleys where the outflow of air is impeded, the layer of air cold enough to produce injury to vegetation may be much deeper than the height of a large tree.

Having described the conditions which lead to spring frosts and their local variations in intensity, the authors next deal with the nature of late-frost injury to trees and shrubs. The susceptibility of a plant to frost injury increases during the spring months. Frosts occurring in May will cause injury to plants and plant organs which sustained much more intense cold in the depth of winter without damage. Any part of a plant which is just about to grow, is growing, or has just ceased to grow is most liable to injury. Whilst the stage of vegetation of a plant has thus an influence on sensitiveness to late frosts, there is plenty of evidence that different species of plants possess different degrees of inherent susceptibility. Thus elms which have already burst their buds are hardier against frosts in May than ash trees which are still in bud at the time.

Several forms which frost injury may take are described, the most serious being such extensive injury to the cambium of the young stem as to cause the death of the plant; next in order of severity comes the killing of the leading shoot resulting in loss of height, crooked stems, and forked leaders. Where, as often in the case of conifers, the bud of the leading shoot has not flushed at the time of frost, damage may be confined to the side branches and the leader grow on unharmed. The seriousness of the damage is also influenced by the size of the tree, not only by its height, which may lift its crown into the warmer layers of air, but also because the loss of twigs, buds, &c., is much less serious for a big tree than for a small one.

The occurrence, distribution, and relative severity of the May frosts of 1935 were determined as far as possible from Meteorological Office data and records from private sources. They allowed of the country being divided into areas of three grades; those in which frost was really severe, those where it was only moderately severe, and those which escaped lightly. Owing to the local variations, many small areas were exceptional to the region in which they lay. A map of Great Britain is given showing the division of the country into seven regions of this kind. On this map an attempt is made to indicate the severity of the damage caused by the 1935 May frosts, each marking on the map being based on information received or collected from a single observation point. Such information was gleaned almost entirely from three sources, reports from the state forest areas, secondly some three hundred letters received in response to an appeal in *The Times* for information, and, thirdly, notes made during personal visits and journeys made during and after the frosts. It is admitted that localities about which information was obtained are very unevenly distributed, and that the observations were made by many different persons, so that the data are not strictly comparable.

Taking the country as a whole, the areas most seriously affected were the south of England (except the south-west and part of the south coast), East Anglia, and the southern half of Wales. The influence of the state of vegetation is apparent. Those areas where growth was backward suffered less severe damage than those in which it was advanced. The information collected as to the damage done to various species of trees and shrubs is analysed, and an order of susceptibility to May frosts is given in the case of trees about which more than twenty reports were received. The species are grouped in three classes. The first contains the frost-susceptible, the second the fairly hardy, and the third the really hardy species. The most important frost-susceptible trees are Sitka

and Norway spruces, Douglas fir, European and Japanese larches, *Robinia*, ash, the oaks, and beech. The only frost-hardy conifer is Scots pine, whilst among the broad-leaved trees in the hardy class are poplars, rowan, birch, hornbeam, lime, and elms. It is pointed out, however, that earlier or later frosts might quite possibly suggest a somewhat different order of susceptibility. Though mainly concerned with the important forest trees, the bulletin contains a great deal of information collected as to the behaviour of ornamental trees and shrubs.

A considerable amount of space is devoted to a discussion of the silvicultural aspects of shelter against frost. The 1935 frosts demonstrated clearly that of all types of shelter, much the most effective is that afforded by a high canopy with the branches almost interlacing above the young plants. Other types may be effective against light frosts but will not keep out frost of any real intensity. Much of the forestry in Britain is concerned with the planting of trees on bare land. In such conditions it may be necessary to employ frost-hardy species on sites which, but for the frost danger, would be capable of growing other and perhaps better species. When a forest crop has once been established, however, it will be impossible to introduce under shelter the more desirable species. Where the land already has tall and worthless scrub or inferior trees left standing after a felling, the ringing and thinning out of the scrub and the retention of the trees will often provide much better conditions for the new crop than if the ground were completely cleared.

Detailed discussion of the weather conditions associated with the late frosts of 1935 forms one appendix to the report. A second appendix deals with the influence of topography on severity of frost. The occurrence of frost damage on selected forest areas covering a number of topographical types is discussed, sketch-maps being given. It appears that whilst topography plays an important part, through its influence on the flow of cold air, the degree of damage may be affected by the stage of development of the plants, which in its turn may be affected by aspect, shelter from the wind, &c. The bulletin concludes with a bibliography and a set of excellent photographs illustrating types of frost damage, shelter, and topography referred to in the body of the work.

NOTICES

Foundations of Silviculture upon an Ecological Basis. By the late J. W. Toumey, second edition revised by C. F. Korstian. Chapman & Hall, Ltd. London, 1937. Price 22*s.* 6*d.*

THE second edition by Professor Korstian of this well-known work will be welcomed in this country. During the ten years since it was first issued there have been considerable advances in knowledge, and the matter has been brought up to date. The book is divided into three parts: The enviromnent of the forest, the influence of the forest on its environment, and the forest. In the first, the following subjects are dealt with: solar radiation, air temperature, atmospheric moisture, climate, soil conditions, soil moisture and its influence on forest vegetation, physiographic conditions, biotic factors, and the interaction of site factors. In the second, the reaction of forest vegetation on its physical environment and the effect of forests on animal life are discussed. In the third, the different aspects of the tree and stands are considered.

As will be seen, the range of knowledge surveyed is wide. The merit of the book is that it is relatively simple, and the points are made by selecting available knowledge and not overlaid by too much data. This is a text-book rather than a mine of existing knowedge. The method has its drawbacks. Emphasis is naturally laid on American work

and conditions, and many of the sections are rather superficially treated. Within the limits of the method and space the book is, however, a good one. More use might have been made, however, of diagrams and illustrations.

(1) *The Practice of Silviculture.* By R. C. Hawley. Fourth Edition. Chapman & Hall. London. 1937. Price 15*s.*
(2) *Forest Protection.* By R. C. Hawley. Chapman & Hall. London. 1937. Price 13*s.* 6*d.*

THE subjects covered by these two books were dealt with in one volume in previous editions of *The Practice of Silviculture.* The third edition was only published in 1934, and little change has been made in the matter included in the first volume. More material is now presented, however, on 'Forest Protection', in particular a chapter on 'Protection against atmospheric agencies'. Erosion is dealt with here, but only in an elementary way. The chapters on forest fires are the most interesting and extensive, describing as they do American conditions.

Elements of Forestry. By the late F. Moon and N. C. Brown. Third Edition. Chapman & Hall. London. 1937. Price 17*s.* 6*d.*

THIS text-book, first published in 1914, is unique in the range of subjects which it covers, silviculture, management, protection, mensuration, wood technology, and timber preservation. In addition the social and economic considerations are discussed, and one can learn about the recent governmental developments in forestry in the United States. Indeed, the general rather than the technical chapters are of most interest. The merit of the book is that it presents a bird's-eye view of the subject as a whole. It is written in an interesting way, and is well illustrated. While it may not increase one's technical knowledge, every one will find something in it which is new to him.

Text-book of Dendrology. By W. H. Harlow and E. S. Harrar. McGraw-Hill Publishing Co., Ltd. London. 1937. Price 25*s.*

THIS volume is one of the American Forestry Series. It deals with the more important forest trees of North America. All the coniferous genera are included, but only a selection of the broad-leaved. The book opens with an introductory section describing flower, twig, and leaf form, then follow the descriptions by class, family, genus, and species. Under species, in addition to botanical characteristics, the range is given, and a brief description of the sites on which it is found associates age at which fruiting takes place, germination, and growth. The seedlings of many species are also illustrated. As the book does not deal with the whole tree flora of the countries or any part of them, keys are not given. The book is well illustrated by half-tone photographs. While these do not give the same detail as line drawings, they probably make it easier for a beginner to recognize the trees. The book is designed primarily as a text-book for students.

Seventeenth Annual Report of the Forestry Commissioners for the Year ending September 30th 1936. H.M. Stationery Office. 1937. Price 9*d.*

DURING the second half of the year under review, steps were taken to give effect to the expansion of forestry work in the Special Areas of England and Wales. The programme for the next three years in these areas is to acquire and begin to plant

100,000 acres and to form 500 holdings. A large new nursery was formed in South Wales and land acquisition is proceeding. Up to May 1937 14,100 acres of plantable land had been acquired.

Coming to the ordinary operations of the Commissioners, the scale of work was similar to that of recent years, 18,244 acres of plantable land was acquired, 20,576 acres planted, 12 acres naturally regenerated, 160 acres under-planted, 3,580 acres thinned, and 507 acres felled. It is stated that the increased grant in aid will be reflected in increased work in the current forest year.

It is of interest that although the number of forest fires was less than in recent years, the area burned, 1,563 acres, and value £20,170, was the highest for some time. The damage was largely done during one week in February, 1936, and in areas which normally have a high rainfall, namely Snowdonia and Nevis.

Forestry Practice. Forestry Commission Bulletin No. 14 (Revised 1937). H.M. Stationery Office. 1937. Price 1*s.* 6*d.*

THE second edition of this useful bulletin does not differ in any important way from the first except that Part V, dealing with conditions on privately owned woodlands, has been omitted.

Within its somewhat limited scope, and at the price, there is no better summary of the work necessary in forming and tending plantations. There is little or no reference to the broader aspects of silviculture or to methods of natural regeneration. Although these have little place in the practice of forestry in this country at the moment, it seems likely that they will become more important during the next decade when the influence of broader forestry education and experience begins to be felt. In the meantime it is certain that this bulletin will continue to help forestry work in this country.

Pit-props. Forestry Commission Special Leaflet No. 1.

THE spectacular rise in pitwood prices during the past twelve months made it desirable that some guidance should be given to landowners and their staffs in taking advantage of it to overtake arrears of thinning in coniferous plantations. It is emphasized that it is highly undesirable that the present demand for pitwood should result in the felling of immature woods; it should be met from necessary silvicultural thinnings.

The leaflet deals briefly but clearly with the preparation and marketing of pit-props, including felling, snedding, peeling, and seasoning. Tools are described and illustrated and average costs given. With regard to marketing, owners are advised to get into touch with the merchants' and growers' associations.

Pruning in Young Plantations. Forestry Commission Leaflet No. 22.

PRUNING is probably being carried out on a larger scale in this country than ever before. This 12-page leaflet gives most of the essential information which is available on the subject both from the limited experience in this country and from abroad. Each aspect is briefly but lucidly dealt with, choice of species and type of stand, season of pruning, selection of stems, method of pruning, a note on live pruning, costs and economic aspects, and tools and equipment.

On the basis of a cost of fourpence per tree for pruning to 20 to 25 feet—a generous figure—it is shown that using 3½ per cent. compound interest and average volumes per

tree taken from British Yield Tables, with normal rotations, the cost of pruning puts one penny or less per cubit foot on the cost of timber. The actual figures are Scots pine, Quality Class II 1·05 pence, Norway Spruce, Q. C. III 0·59 pence, and Douglas fir, Q. C. III 0·34 pence. Provided pruning is well done, and there is no trouble with resulting fungal staining of timber which has still to be determined, pruning should be a very profitable operation in this country. Partly as the result of our methods of artificial formation, but principally because of our climate, our timber is rough, and clean timber will fetch much more than an extra penny a cubic foot.

The Causes of Stain and Decay in Imported Timber. Forest Products Research Records, No. 18. H.M. Stationery Office. Price 6*d*.

THIS publication by Mr. K. St. G. Cartwright should be of considerable assistance to the timber trade. Discoloration of timber may be due to chemical or biological agencies, and the distinguishing characteristics of each are given. Then follows a section on decay-causing organisms. The most important factor governing the development of stain and decay is the moisture content of the timber, and if this is reduced to below 20 per cent. and the timber subsequently kept dry, it will not suffer from these defects. Where this is not practicable the use of antiseptics after conversion is advocated. The publication is well illustrated and there are appendices on 'Method of preparing wood sections for microscopic examination' and 'a method of determining moisture content'.

Methods of Bending Wood by Hand. Forest Products Research Bulletin No. 17. H.M. Stationery Office. 1937. Price 1*s*.

THIS bulletin by Messrs. W. C. Stevens and M. Turner describes methods and equipment for softening timber prior to bending, for bending, and for setting bends. Although bending by machinery is coming more into use, the plant required is often too expensive for small firms, and this bulletin should, therefore, be useful. It is well illustrated.

Forest Bibliography to 31st December, 1933, pt. II. B. Silviculture (continued). Department of Forestry, University of Oxford. Price 12*s*. 6*d*.

PART I was referred to in *Forestry* X (2). The present part covering natural reproduction, artificial reproduction, tending, silvicultural systems, and notes on trees is of much greater interest. A large number of references are given in each of these subjects, the first dating in several instances from the beginning of last century. The library on which it is based must be the most extensive forest library in the Empire, hence this bibliography is the best we are ever likely to get in English, and the Oxford Department of Forestry is to be congratulated on undertaking it. When completed it should be a monumental work.

The Beech in Denmark. By L. A. Hauch.

THIS veteran Danish forester has again done English-speaking foresters the honour of issuing an English edition of his monograph on beech; and we want to convey to him our thanks and best wishes for continued activity.

The monograph consists of three parts: the relation of beech to the site, the cultivation of the beech, and the thinning of beech trees. In the first part the importance of spring and autumn frosts as factors in limiting successful cultures of beech is empha-

sized. With regard to soil, it is stressed that while good beech is often associated with lime-rich soils, it is not necessarily confined to these. The work of the famous P. E. Müller on mould and duff soils is dealt with, and the danger of introducing spruce into beech cultures stressed.

In the second part the point that is emphasized is the necessity of a dense crop. Natural regeneration frequently does not give the required density, and success with direct sowing is uncertain; while planting with naked roots is condemned. What is termed block-planting is advocated. When there is a large mast, nursery beds are made in the beech woods and dense crops of beech seedlings raised in furrows. These nurseries have to be on heavy soils, because clumps of soil with beech seedlings are dug up and these clumps planted under the shelter of part of the old crop. In addition, the planting soil is dug over. Up to 200,000 seedlings per hectare are thus planted. No cost figures are given, but these must be very high.

In the third part the thinning requirements of beech are discussed. Here also dense crops are advocated, leaving nature to select, and merely removing trees menacing better trees. The author criticizes the recent tendency to heavy thinning. He is a devotee of the 'close forest' in distinction to the selection type.

The Call of the Koala. By Ambrose Pratt. Robertson & Mullens, Ltd. Melbourne, Australia. 1937. Price 6*s.*

THE attention of all who know this charming animal in its native habitat and who are interested in natural history is drawn to this book. The Australian Koala has been called the prototype of our teddy bears, but judging from the excellent photographs in this book it is much more attractive than even our best. The Koala has a special interest for foresters in that its food is exclusively the young leaves of different species of eucalyptus, the different sorts prefering different species. Mr. Pratt deals exhaustively with his subject, but in an interesting way, and the book can be recommended, especially at its low price, considering the number and excellence of the illustrations.

The Dragonflies of the British Isles. By Cynthia Longfield. Frederick Warne & Co., Ltd. London. 1937. Price 7*s.* 6*d.*

THIS is the latest addition to the 'Wayside and Woodland Series'. It follows the general plan of this series and is profusely illustrated.